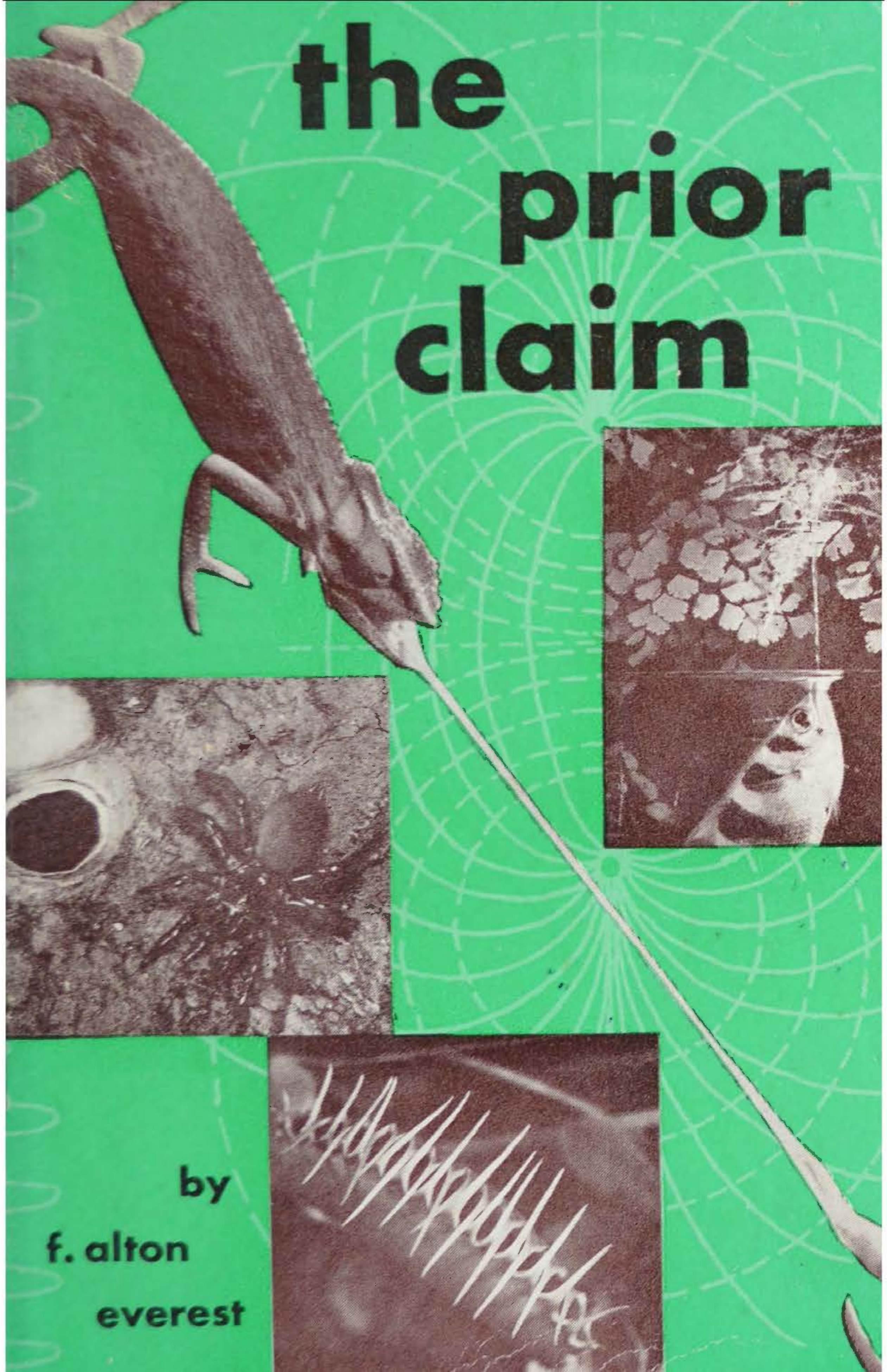
the prior claim



by

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THE PRIOR CLAIM

The amazing story of the way humble plants and animals have anticipated man's greatest inventions.

By

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PREFACE

THIS BOOK IS WRITTEN to supplement the Moody Institute of Science film, *The Prior Claim,* released during the fall of 1953. While the general organization and argument follows quite closely that of the film, it has been possible to include much more information on the various subjects in this book. This more complete, written supplement, including a reasonably comprehensive bibliography, has been found to meet a need among students, teachers, and others desiring more information than included in the motion picture.

This is a scientific age. Discoveries and inventions are tumbling pell-mell over each other as they pour off a virtual production line from research laboratories, industrial concerns and universities. The technical journals are fatter and more numerous than ever before. Along with the rise of scientific knowledge has grown a materialistic philosophy. It is the firm conviction of those of us at the Moody Institute of Science that little justification for such a trend can be found in science itself. We firmly believe that this tendency to leave God out of the picture is warping our outlook, retarding scientific advance, and blighting the minds of students and leaving them without purpose and without spiritual stability.

This materialism which has become a camp-follower of science has provided a fertile soil for the growth of a smugness among scientists. After all, there is cause for pride; look at all that has been accomplished! True, many wonderful inventions have funneled through the patent office, many advances in scientific understanding of the world about us have taken place. However, a very remarkable thing has become increasingly evident in recent years: Even though man might have conceived his invention, without his knowing it, nature beat him to it! This has happened in so many instances that scientists are now prone to look to nature for the solution of exceedingly difficult problems confronting them. This book treats a number of specific examples of how nature anticipated the inventions of man and that actually God had the prior claim.

A firm such as *The Prior Claim* would be impossible without the co-operation of many scientists and other friends. Such co-operation has been given most gladly and willingly, and we wish to express our deepest gratitude for it. Specific acknowledgments will be found in the appendix.

The normal situation is for this little book to follow in the wake of the film of the same name. This order may be reversed, and if the reader desires further information on Moody science films he may write to the Film Department, Moody Bible Institute, 820 N. La Salle Street, Chicago 10, Illinois.

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Chapter 1

NATURE: PATENT PENDING

"Build a better mousetrap and the world will beat a path to your door." This has been the advice of countless fathers to their sons and has become the motto of nineteenth and twentieth century legions bent on applying the forces and laws of nature to the use of man. The sons have shown a remarkable genius in pursuing this mousetrap business. There has probably been more technological advance during our lives and the lives of our grandparents than during all the rest of human history. The span of a single lifetime these days is sufficient to witness a great panoramic sweep in material advances almost unbelievable in scope.

THE LANDSLIDE OF PATENTS

The best barometer of technological advance is found in the activities of patent offices. Man wants protection on these wonderful ideas of his, and the governments of the various countries have set up legal safeguards which insure the one conceiving the invention the right to exploit it.

Since the adoption of the 1790 patent laws by Congress, almost two million patents have been issued, each purporting to be a new application of basic physical laws to the needs of man or the improvement of existing machines or processes. This new era has seen great advances in chemical processes, steam engines, various machines for

transportation in the air, on the land, or under the sea, communication devices for sending intelligence from point to point in the form of human voice, code, facsimile, or by television, great advances in manufacturing processes, in the utilization of the natural resources of our planet such as coal, petroleum, water power — yes, even the changing of mass to energy in nuclear fission or in thermonuclear reactors.

Many inventions are the outgrowth of preceding developments and patent examiners are continually faced with a number of patent applications on similar devices or processes. When this happens, the patent applications go into what is called "interference." It is then determined which inventor is entitled to the prior claim. Thus man contends with man as to who was first, but we shall look into this problem a bit and see just where these ideas originated. Were they first conceived in the mind of man or in the mind of God?

IMPROVING ON NATURE

Until the last few decades man thought that it was necessary to improve upon nature in order to make significant advances. Today, however, we see a humility among men of science and engineering as they go to the lowly plants and animals to learn lessons in structure, design, and function straight from the hand of the Creator. Everything is under study: flowers, grass, marine plants, birds, insects, mammals, and even the human body itself. The structural engineer is carefully searching the shapes of nature and is finding paper-thin tubes, rods and corrugated sections sustaining tremendous loads. The electrical engineer is watching with fascination the research work on electric fish as he contemplates their thousands of watts of biological power. And the aeronautical engineer — ? A whole new

field of investigation into the flight instruments of insects has amazed aircraft designers as they see remarkably effective control devices packed into unbelievably small spaces.

STRUCTURAL SHAPES

The modern architect and structural engineer are looking to nature for the shapes of things to come. Frank Lloyd Wright, the famous architect, copied the morning glory in his design of one of the simplest and strongest buildings in the world. Thin-stemmed concrete pillars flaring out to broad discs at the top serve as supports for the roof.

The egg has been one of the most copied shapes in nature. While egg shells are thin and brittle, four eggs can support the weight of a man if the load is properly distributed. The Quonset hut utilizes egg shell principles and Buckminister Fuller designed his "Dymaxion" house around the thin-shell principle. The continuous curve of the thin shell is utilized in large aircraft hangars, auditoriums, and other large structures which need a maximum of volume without troublesome roof supports.

During Otis Barton's record-shattering descent in the Benthoscope in 1949, the writer became interested in the wardroom discussions of the journalists. Some insisted that the egg is so strong that it could descend as deeply as the mile Mr. Barton was intending to descend on the morrow and still withstand the terrific pressures of the water at that depth. The next day, unknown to Barton inside the Benthoscope, one of the reporters wired a tin can to one leg of the sphere and in this can carefully placed an egg protected by excelsior. I fear that there were some individuals that were more concerned about the egg outside than for the safety of the man inside. Unfortunately, the question of the ability of the egg to withstand such pres-

sures remains unanswered to this day because the great force of current swept away the egg, can, and all. My curiosity is still keen on this subject, and I hope someday that the egg and I will be able to continue this experiment.

In other areas of nature we find improvements on the egg shape. In the case of the shell of the turtle the half shell is strengthened by the tension plate beneath. The heavy compression ring about the center of the walnut shell and the corrugations over its entire surface provide a great increase in strength without increasing weight — solving a problem of continual concern to industrial designers.

The United States Navy recently designed a light-weight salvage pontoon capable of supporting 75 tons. This pontoon resembles a balloon and is secured to the sunken vessel in a deflated condition and pumping air into it provides the lifting force. However, as the inflated pontoon nears the surface, the tensile stress in a smooth skin would be sufficient to tear it apart. This was solved by shaping the pontoon from sections like the cantaloupe or pumpkin which provided the necessary strength.

The largest grain storage elevator in the world is located at Enid, Oklahoma and is operated by the Union Equity Co-operative Exchange. It is significant that this behemoth of elevators utilizes a new shape, that is, new to grain elevator construction men, but as old as life on this planet. Instead of the usual cylindrical shapes, closely stacked bins of hexagonal cross section are used, just like the cells of a honeycomb. Stacking of square sections together would result in a saving of material, but would waste space. Stacked cylinders use too much material. But stacking hexagonal polygons together attains greatest economy of space and material, and the greatest strength. Here again, the

biggest and best that man has made was anticipated by the Creator in the honeycomb instinctively shaped by the bee.

FLIGHT INSTRUMENTS OF INSECTS

In common with aircraft or any other airborne object, the insect must receive positional data in six spatial coordinates in order to achieve controlled flight. The insect can go forward, backward; up or down; left or right. These directions are recognized as the x, y, and z axes of geometry and serve to define translational movement. These do not describe all motions, however, as the insect could be progressing in a forward direction but head over heels, for example. Thus we see that there are also rotational motions which the insect must cope with which, in aeronautical or sea-going language, are termed pitch, roll, and yaw, depending upon which axis the body rotates about. In addition to these six degrees of freedom of the insect, the element of time must be added, making a total of seven factors which must be under constant control for successful flight.

It is typical of the times to learn that the Institute of Navigation recently was addressed in New York by Professor Talbot H. Waterman, Professor of Zoology, Yale University. What can a zoologist tell navigators about navigation? Professor Waterman drew many lessons from birds, bees, and fish which were of direct value to the navigator, and the zoological research now being conducted along these lines is of such value that it is being sponsored by the Office of Naval Research. Let us study some of the flight instruments utilized by insects.

INSECT AIR SPEED INDICATOR

The antennae of insects are known to have a number of functions. Mosquitos hear by them. Some beetles use

them in obstacle avoidance. The work of Hollick in England has now clearly indicated that the antennae in the fly *Muscina* measure the velocity of the air stream in flight. Hollick placed a fly in a miniature wind tunnel by attaching it to a fine wire with a bit of wax. He found the velocity of the air stream influenced the manner of beating of the wings. In further experiments, he explored with a tiny jet of air over the body of the fly and found that only when the air jet hit the antennae were the characteristic reactions evoked. He found specifically that movement of the third joint of the antenna was all that was necessary to get the response. Some day this work can be greatly furthered by a study of the nerve impulses carried by the nerve leading to this third joint, but there is no doubt that here is the air speed indicator of the fly *Muscina*.

INSECT TURN INDICATOR

A fast-flying insect must have some method of indicating rate of turn. This is done by gyroscopic precession in the airplane instrument used for this purpose, but we wouldn't expect rotating gyroscopes in insects. This is especially unlikely when we consider that in all of nature it seems that the wheel and the axle are the only mechanical principles that are not to be found. Engineers of Sperry Gyroscope Company have examined insects to find out how the gyroscopic effect is obtained by vibrating mechanisms. By means of high-speed motion pictures, the action of the "balancing" organs or, more properly, the halteres of the two-winged insects or flies, has been carefully studied. These organs have been known for a long time, but their complete significance was not probed until the last few years when the excellent research work of Professor J. W.

S. Pringle of England revealed the marvelous nature of this mechanism.

The halteres are a pair of tiny club-shaped organs protruding from the thorax, one under each wing. As the wings beat in flight, the halteres also vibrate in a vertical plane. As the wing goes up, the haltere under it travels downward. The bulbous end acts as a weight on the end of a reed and it is this oscillating mass which gives rise to the vibrating gyro effect. As the body of the insect turns, this bulbous mass tends to continue to vibrate in the original plane and the stress at the base is translated into nerve signals which give the insect the necessary turn-indicating data.

INSECT POLARIZED LIGHT COMPASS

It has been known for many years that ants, beetles, spiders, caterpillars, and other insects find their way with a sort of sun compass. With this compass they orient their travel so that the image of the sun on the retina of their eye will remain in the same spot. If they succeed in holding this image on one spot, they will travel in a straight line. Von Frisch's work with honeybees, however, indicates that there is another element present for the bee is able to determine its course without seeing the sun directly. He has demonstrated that the bee uses the polarized nature of the light from the sun for this cue. All the bee requires to navigate is a view of a small patch of blue sky.

While the insects have been using the polarized light compass from the beginning, man has but recently discovered how one could be built. The Pfundt sky compass has proved to be useful in navigation in polar regions. At the poles there are eight days between the time of the final disappearance of the sun and the first appearance of the brightest stars. During this time the standard celestial

navigation equipment is inoperative, and the magnetic compass is also unreliable near the poles. The Pfundt sky compass is a very feeble step in the direction of using this polarizing effect which is used with complete success by the insects.

ANIMAL TOOLS

Man is inclined to think that it is the matter of tools which casts so definite a line of demarcation between the activities of intelligent man and the beasts. When archaeologists find tools and implements, no matter how crude, they know that intelligent man has been at work. We cannot say that the wisdom of the wild is greater than that of man, but it is definite that the Wisdom behind the animals, the Implanter of instincts, the Designer and Builder of peculiar organs for specific jobs, is most assuredly greater than man.

The study of nature is replete with examples of tools vitally needed by the organism and artfully contrived to serve its purposes. Insect drills differ greatly from the rotating drills of the machine shop, but they are no less effective for their task. The female 17-year cicada lays her eggs in the green limbs and twigs of trees and the instrument by which this amazing task is accomplished is in many ways more wonderful than man's most complicated drilling device. It is composed of three sections, beautifully interlocked with tongue and groove key so that the sections can move with respect to each other and yet be held together. At the end of these sections are minute saws which penetrate the wood fibers as they are moved back and forth. The eggs are passed down a groove and deposited deep within the fibers of the wood.

The mosquito has one of the most complete surgical kits found anywhere in nature. As one watches a mosquito bite, it apparently is merely the penetration of the skin of

the victim by the beak. Studying this beak under a microscope shows that it is actually a whole bundle of delicate surgical instruments. The bundle contains two lancets, two saws, a saliva syringe by which saliva is pumped to prevent the blood of the victim from coagulating, and a food syringe which syphons blood from the pierced blood vessel. As one watches this operation under the microscope and understands the uses to which the implements are put, one considers with amusement the relatively crude and clumsy tools of man.

One could say, "These aren't tools in the strict sense of the word, these are the organs with which the mosquito and other insects are equipped. These are not external tools used to accomplish specific purposes." Possibly, but how about the sea otter? He has been observed diving off the California coast and when it comes up with a shellfish, it also brings a rock upon which to crack the shell. Floating upon its back in characteristic style the sea otter places the flat rock on its chest and lustily proceeds to crack open the shellfish and enjoy the contents. No less amazing is the wasp which holds a small stone in its mandibles and tamps the dirt into the entrance of its tunnel after the eggs are laid. And this is no more unusual than the sewing machines which certain tropical ants have. The ants make their homes out of leaves which are rolled until the edges touch. While they are held in this position by other ants, the seamstresses get to work using a baby ant as the needle. The baby ant is held in the adult's mandibles and moved back and forth across the edges to be sewed, all the while the baby ant spins a transparent thread which sticks the edges together. The inside of this leaf nest is lined with the same silky material. Normally this silky material would be used by the baby ant to spin its own

cocoon in which it would await the transformation to the adult stage. For some reason unknown to man, these adult ants use the baby as a living sewing machine rather than let it build its own protective house.

So we could go on with insect tools and more insect tools, nature's counterparts of the tools man has devised for his own use: The pincers of the beetle, the bee's bottle-brush tongue, the hooks on the fly's feet so that he can walk upside-down on the ceiling, the saw-fly with a gimlet that bores holes in wood, the nut-cracker arms of the praying mantis, the combs on the spider's feet, and on, and on . . . . and on.

TOOLS OF WARFARE

Of all aspects of modern warfare copied directly from nature, the art of camouflage is certainly the outstanding example. Mimicry in form and color in the animal world has provided the pattern for man. The chameleon is known for its color shifts as is also the squid. The moths on the bark of the tree, the game birds in the field, all show a wide variety of ways of solving the common problem of concealment. The walking-stick insect utilizes not only protective coloration, but also his very form is designed to conform to the twigs upon which it lives. Other insects look like thorns.

Poison gas warfare is not unknown in the realm of nature. The mink lays down a sickening defense in the form of a bromide-like odor. The skunk's defense may not be unique, but it is probably one of the most successful, as both man and animals show great respect for the ability to protect itself with both barrels.

There is nothing new about this modern smoke screen business — either the usual smoke screen laid down to hide military operations from the eye of the enemy, or the

barrage of tinfoil strips dumped from planes which serve the same purpose of keeping the penetrating eye of radar from knowing what is going on. The squid's ink sac discharges into the jet of water by which it propels itself. Thus in a single offensive stroke it escapes from its adversary and confuses the enemy with low visibility.

Primitive warfare depended largely upon arrows and darts, many of the tips being poisoned. This poison dart idea permeates the animal world down to the very smallest and most obscure forms such as the hydra, a tiny protozoan which stings its prey into submission, and the jellyfish, whose stinging tentacles are all too familiar to unwary swimmers. The hairs of caterpillars, the poison spine of the bullhead fish, and the fangs of snakes are other prominent examples of this form of protection and attack.

NATURE'S FIRSTS IN TRANSPORTATION

Jet propulsion is coming into its own these days as far as man is concerned, but the humble cephalopods living in the sea have depended upon this form of propulsion since the time of creation. The squid and the octopus are somewhat more familiar examples of the use of jet engines.

The streamlining of bodies is a necessity for rapid travel, whether it be through the air, on land, or under water. The clean-cut streamlining of fish is a classical example of the priority of nature in such things. In designing his boats, man has carefully studied the way fish are built. During World War I the British made a careful study of the blue whale in arriving at the best shape for their submarine hulls so that they might have a minimum of drag in the water.

Speaking of submarines, was the periscope one of man's firsts? How about the stalked eyes of many of the deep sea fish, of the common snails, crabs and lobsters? These

strange eyes set out on the very tips of long stalks functionally anticipated the periscope.

The screw of the ocean vessel or the propeller of the airplane are similar in principle to the wing of the bird, the fin of the fish, or the flippers of the seal. To this basic idea, man has added his one apparent contribution, the wheel.

OTHER FIRSTS IN NATURE

There is no limit in this business of making these comparisons except the limit of our own interest and patience, but there are several others which should be included for their very importance. Imagine if you can a primitive man fishing with a line of sinew and a hook of bone. There was a first time that man did this; was this the first time that it was done? Only within recent times has the great angler fish been hauled up from the extreme depths of the ocean where it lives. It is not a large fish, but what he lacks in size he makes up in clever fishing equipment. From the top of his oversized head there grows a graceful, slender fishing rod of cartilage, and from the end of this rod there hangs a flexible line as long as the rod. That is not all. At the end of this fishing line there is a three-barbed fishing hook and illuminated lure. As one magazine observed shortly after the discovery of this fish, "The only thing it lacks is a pair of hands to show how large the fish were which got away."

The firefly needs but to be mentioned to remind us that biologically produced light was here long before man lit the first candle. Not only that, but there is now great research activity to try to determine how animals produce their cold light. In the usual incandescent lamp, about 98% of the energy is wasted as heat. In the lucifern of the animal world the efficiency of cold-light production is amazingly high, approaching 100%.

But surely man invented bifocals, didn't he? The answer is "no," for there is a fish which lives in the rivers and lakes of Central and South America, *Anableps* by name, which comes equipped with bifocal eyes. Its habit is to swim near the surface with parts of its eyes protruding from the water. The upper parts of the eyes are suitable for vision in the air, the lower submerged parts suitable for water. Thus *Anableps* looks for floating food and for enemies beneath the water simultaneously by the aid of the most amazing eyes in all of nature. Our bifocal spectacles appear to be very simple affairs compared to the eyes of *Anableps*, the four-eyed fish.

Nature's clocks are in many forms. Actually all that our clocks and calendars do is to provide a means of conveniently dividing the time intervals established by the solar cycle. There are many biological clocks such as used by the grunion fish to time its spawning with such precision, or by the crawfish whose eyes light up the same time every night. Even more impressive are the physical means of reckoning time the Creator built into this world when He created it. Based upon the radioactive disintegration of uranium, rocks containing this element and its disintegration products can be dated by the physical chemist. With the carbon-14 method, also based upon radioactive disintegration rates, it is possible to determine how long ago once living objects died and were removed from the carbon dioxide cycle.

By means of the carbon-14 method, the approximate time has been determined when the sheep were killed to make parchment for the Isaiah scrolls recently found near the Red Sea and the date a tree was cut down to make a coffin for an Egyptian pharaoh.

Chapter 2

NATURE HAD THE FIRST AND FINEST TRAPS

THE VERY SYMBOL of man's inventive genius, the better mousetrap, is neither better, nor was it first. In this area of traps, man's prior claim is most easily refuted. When the first man to build a trap looked with satisfaction at what his hands had wrought and in anticipation at the food it would catch for him, little did he realize that throughout the realm of nature God had placed a profusion of traps in the animal and plant kingdom. His bear trap, his flypaper, his pitfall have all been preceded by highly complex and extremely efficient prototypes in the lowly green world of the plants. And the amazing thing is that these plant traps are for the purpose of catching meat for the plants to eat!

The meat-eating plants are among the greatest oddities of nature. Perhaps we are not justified in considering these plants oddities, but in some way it just seems normal that animals should eat plants and abnormal for plants to eat animals. From the botanical standpoint there is surely no reason to consider carnivorous plants odd or rare for there are about 450 species of plants which depend in part upon food which they trap. And the remarkable thing is that the 450 species are spread throughout 15 genera and 6 families. This means that nature has applied the idea of

plants obtaining food from animals in many ways. There are pitfalls which rely upon luring insects to their brim where falling into the murky insect soup below is very easy, and climbing out is made very difficult in a number of ways. There are traps which depend upon sticky substances to trap the prey. This method is similar to flypaper in its action, but the similarity ends there, for the insects are also digested. There are also two types of active traps which actually snare their prey; the triggered bear-trap type, and the trap which sucks its prey into the interior.

Besides the varied forms of traps, there are likewise many lures in use to coax the prey into the trap, or to the tripping mechanism. Some specialize in a fragrant odor of violets, or the secretion of a honey or nectar. Others use color profusely and some have bright points of light caused by reflections of the sun in minute globules of clear, sticky, secreted liquid, acting like the facets of a diamond. Besides these special structures and functions of alluring and trapping the prey, we find means of digesting it by the secretion of enzymes and acids, much like animal stomachs. What is really amazing is that in certain of these plants, which have neither muscle tissue nor nervous system, electrical activity accompanies trap actuation.

The prey of these plant traps is varied: there are insects and small vertebrates such as frogs and small birds for the traps growing in the air. The traps growing under water catch freshwater crustacea, worms, and various aquatic larvae.

Lloyd, in commenting on the evolutionary significance or origin of the carnivorous plants, said, "How the highly specialized organs of capture could have evolved seems to defy our present knowledge."

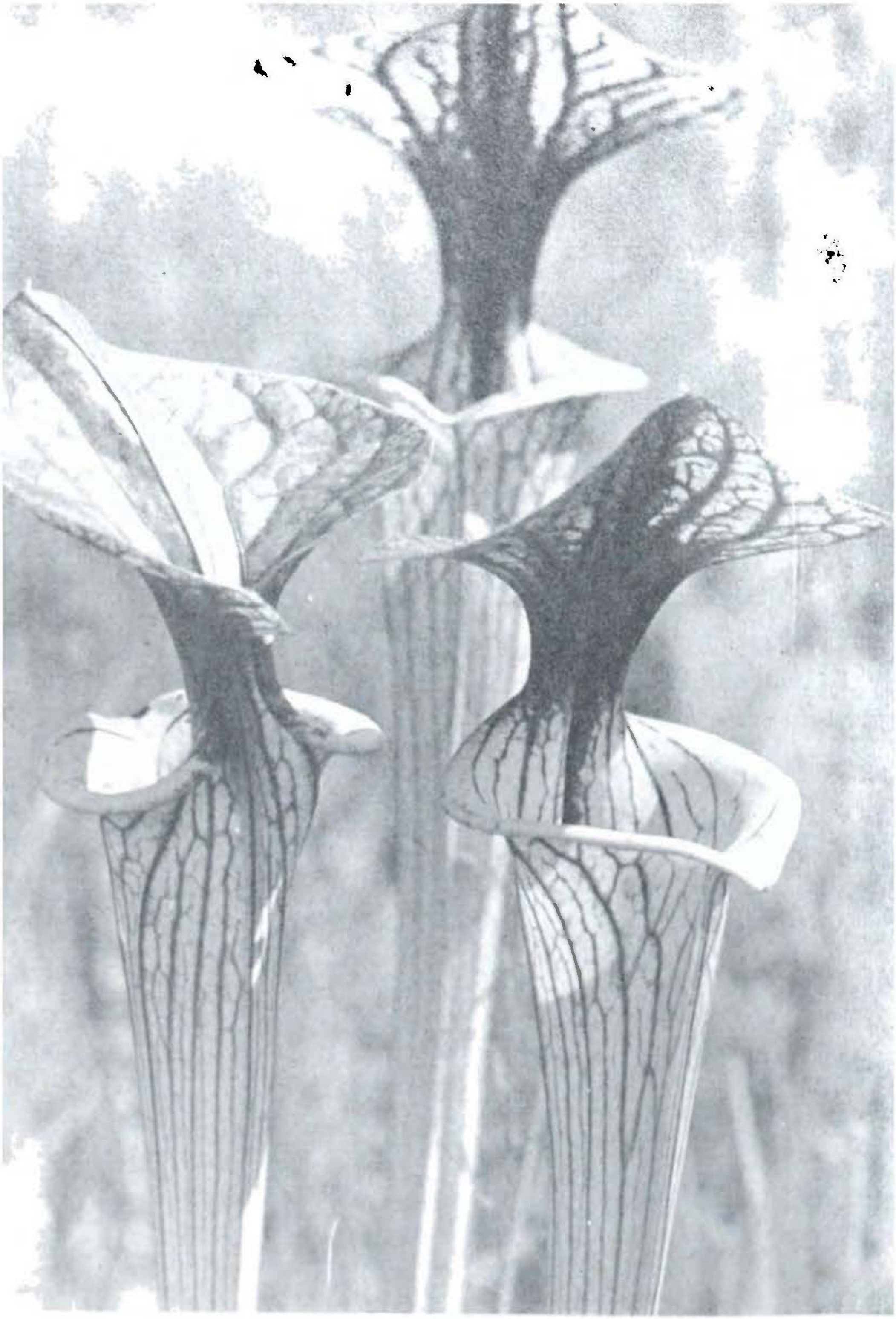
The mouth of the pitcher plant showing hairs inclined downward.

In order that we may better appreciate how thoroughly and completely God has preceded man in this matter of invention of traps, and how much more complex and effective the plant traps are than man's crude contrivances, we shall study these unusual plants in some detail. A careful look at the pitcher plants, the sundew, Venus's-flytrap, and the bladderworts will demonstrate conclusively that when it comes to devising traps, man is all thumbs!

THE COMMON PITCHER PLANT

The common pitcher plant (Sarracenia purpurea) is found in marshes of the North American continent from Hudson Bay to Florida. Its commonness, however, applies only to its wide geographical spread and not its structure, for it is a very efficient pit of death. The leaves of this plant are in the form of curving receptacles which are small at the base where they are attached to the plant, and flare out until they are 1 or 2 inches across at the mouth. The pitcher is 6 or 8 inches in over-all length. A cluster of these leaves forms a rosette of pitchers snuggled closely down into the moss of the bog. The stems bearing the flowers arise from the center of the rosette.

The pitchers were originally thought to be only for catching rain water for the nourishment of the plant during periods of drought. It is hard to see how such an answer gave much satisfaction, for the plants are almost invariably found in the very wet, soggy conditions of marshes, swamps or bogs. A truer indication of the function of these traps was demonstrated by Lloyd on another of the pitchers (*Sarrancenia drummondii*). He placed one of the traps in a vial of water under a bell jar and placed a blue bottle fly inside. Soon the fly was attracted to the nectar near the opening and worked its way to the rim. There it sipped the nectar — frequently holding on only



Insects are attracted to the trumpet plant by the dark-red coloring of the veins and the fruity-smelling nectar secreted around the opening of the plant.

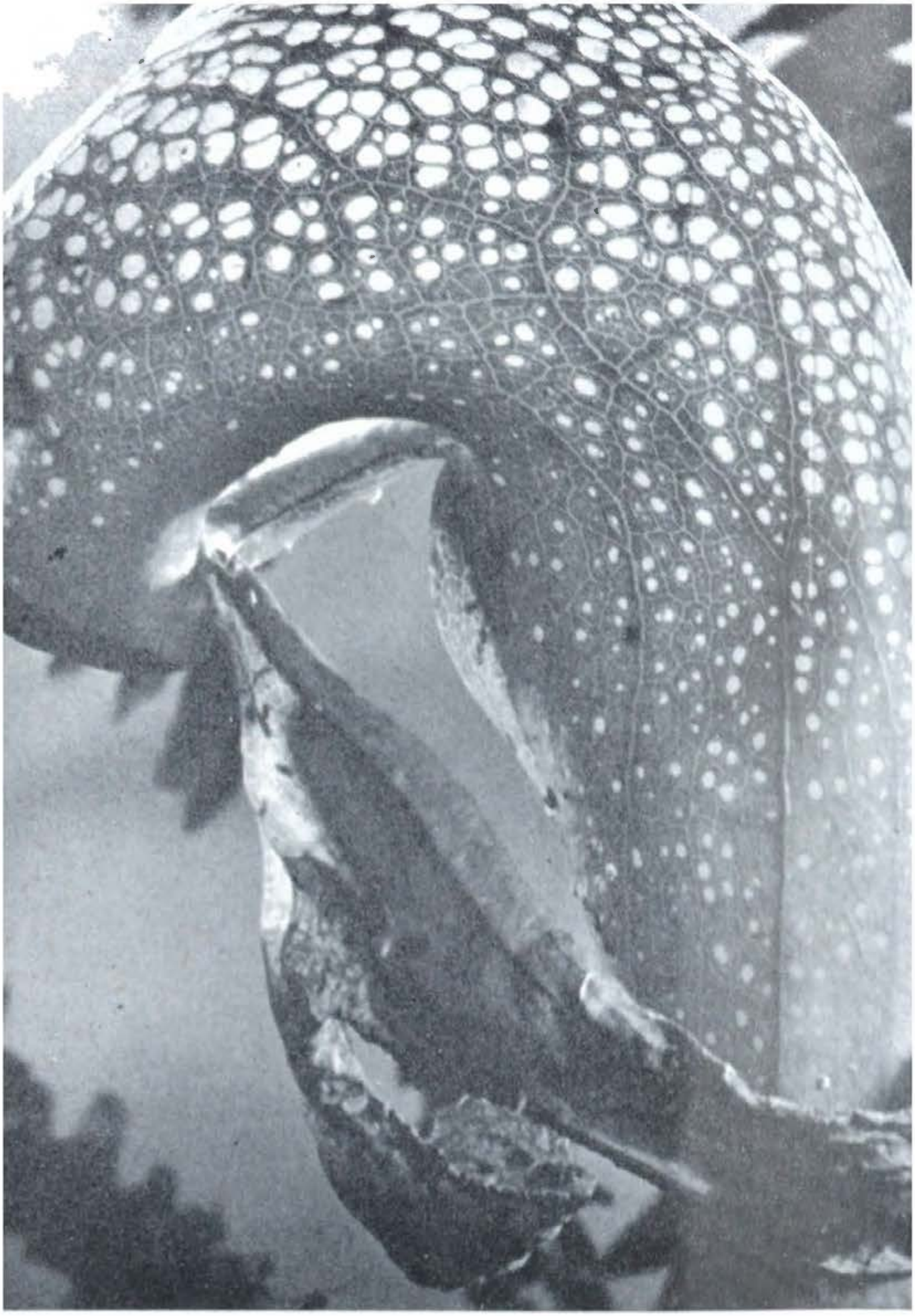
with its hind legs in order to reach the nectar just under the lip. It was not long before it fell into the abyss of the trap. Here it crawled out through a hole thoughtfully cut by Dr. Lloyd just above the water line. Not having learned a lesson, the fly again succumbed to the entrancing aroma of the nectar and again climbed up to the lip of the pitcher, only to fall in again. The fly repeated this procedure a dozen times and was trapped each time. This demonstrates the attracting effect of the nectar and the efficiency of the trap itself.

As the insect falls into the trap, it splashes into a concoction which can best be described as "insect soup." Surely "water" is too simple a term to describe the liquid fortified as it is by the remains of scores of other insects which have been trapped. To the water is also added certain materials exuded by the plant from the inside surface of the trap which serve to stupify, kill, and digest the insect. One thirsty scientist sampled the water from a tropical pitcher plant and announced that it was not too unpalatable.

The inside walls of the trap have a very smooth surface making it almost impossible for the drenched insect to gain a footing. If it should find such a footing, however, and begin its climb back to the lip of the pitcher, it would encounter a thick carpet of hairs pointed downward against which it can make no progress. These very hairs which prevent the insect from climbing out of the trap, form a smooth "chute-the-chute" on the way down.

THE TRUMPET PLANT

Another of the pitcher plants is the so-called trumpet plant *(Sarracenia flava)*, a tall and beautiful greenish-yellow plant which is found in North and South Carolina, Georgia,



The head of the cobra plant *(Darlingtonia californica)* with its "skylights."

extreme Northern Florida, and Southern Alabama. These southern trumpets are among the tallest of the trumpets. They average about 18 inches or 2 feet in height when mature. The slender tube is small at the base and widens gracefully toward the open mouth, much as a tall flower vase. The opening is covered with a roof-like lid which is held up by a neck and looks much like a jack-in-the-pulpit. The lid, the support of the lid, and the trumpet itself are frequently highly colored with red vein-like markings. These plants are also equipped with nectar glands which exude a honey-like substance attractive to the insects forming their prey.

THE COBRA PLANT

The cobra plant *(Darlingtonia californica)* is another pitcher plant which has a tall, slender, tapered trumpet but which has a beautifully curved hood over the top shaped much like the head of a cobra. The only place in the world where this plant is found is in a small region extending from Mt. Shasta in Northern California as far north as Florence, Oregon. The plants attain a height of 2 feet and occur in rosette clusters as the other pitcher plants.

The dome of these plants is quite unusual in that it is covered with many small transparent windows ranging in size up to approximately ¼ inch in diameter. This dome is formed by a widening of the tube at the same time that it is curved sharply over, bringing the mouth into a horizontal plane under the hood. At the outer edge of this mouth, two leaf-like appendages, joined at their base but twisting outward from each other, provide for insects alighting upon them a path to the rim from which they can easily fall into the water in the stem. These appendages look very much like a walrus mustache hanging down, but, unlike this human hairy adornment of a bygone day, secrete

nectar as a lure for the insect prey. They also provide an excellent landing field. The complete absence of chlorophyll-bearing tissue and of intercellular spaces in the windows of the hood gives them a glassy-clear transparency. The fishtail walrus mustache on the small immature leaves touches the ground and provides a ramp up which insects may crawl from the ground to the trap. The rolled edge around the mouth of the trap secretes nectar abundantly, and the walrus mustache provides the inclined surface for the insect to reach it. The hairs which grow on this appendage slope upward toward the fragrant rolled edge in such a way that the insect is assisted in this one-way trip.

Once inside the hood the insect encounters another forest of hairs, all directed to assist it to its doom. The inside of the dome nearest the entrance is a very convenient feeding platform, but the rear part has no nectar glands, only these hairs which offer scanty foothold. Should the insect attempt to fly upwards toward the light, he will hit the windows and be knocked down into the insect soup below. If he elects to continue to work his way around the lip against the stiff opposition of the hairs, the chances are excellent that he will sooner or later lose his foothold and plunge into the depths.

The water in the bottom of the cobra plant cannot come from the rain as the top of the hollow leaf is completely covered by the hood. The only opening to the reservoir opens downward underneath the hood. The common pitcher plant is wide open to the rain and the trumpet's hood is more or less flat and placed some distance above the mouth of the hollow leaf allowing considerable amounts of rain to beat in. However, in the cobra the plant relies entirely upon the water brought into the trap through the root system of the plant, an effect which is present in some

degree in all of the pitchers. In this water, the digestive processes are at work, whether they be of bacterial or of digestive ferment origin. The inner surface of the lower part of the hollow stem of the cobra leaf is bare of cuticle and absorbs the nutritive products from the insect soup. Scientists are inclined to believe that this plant depends upon bacterial action for breaking down the soft parts of the trapped insects, a suspicion shared by anyone who has taken a sniff of the contents.

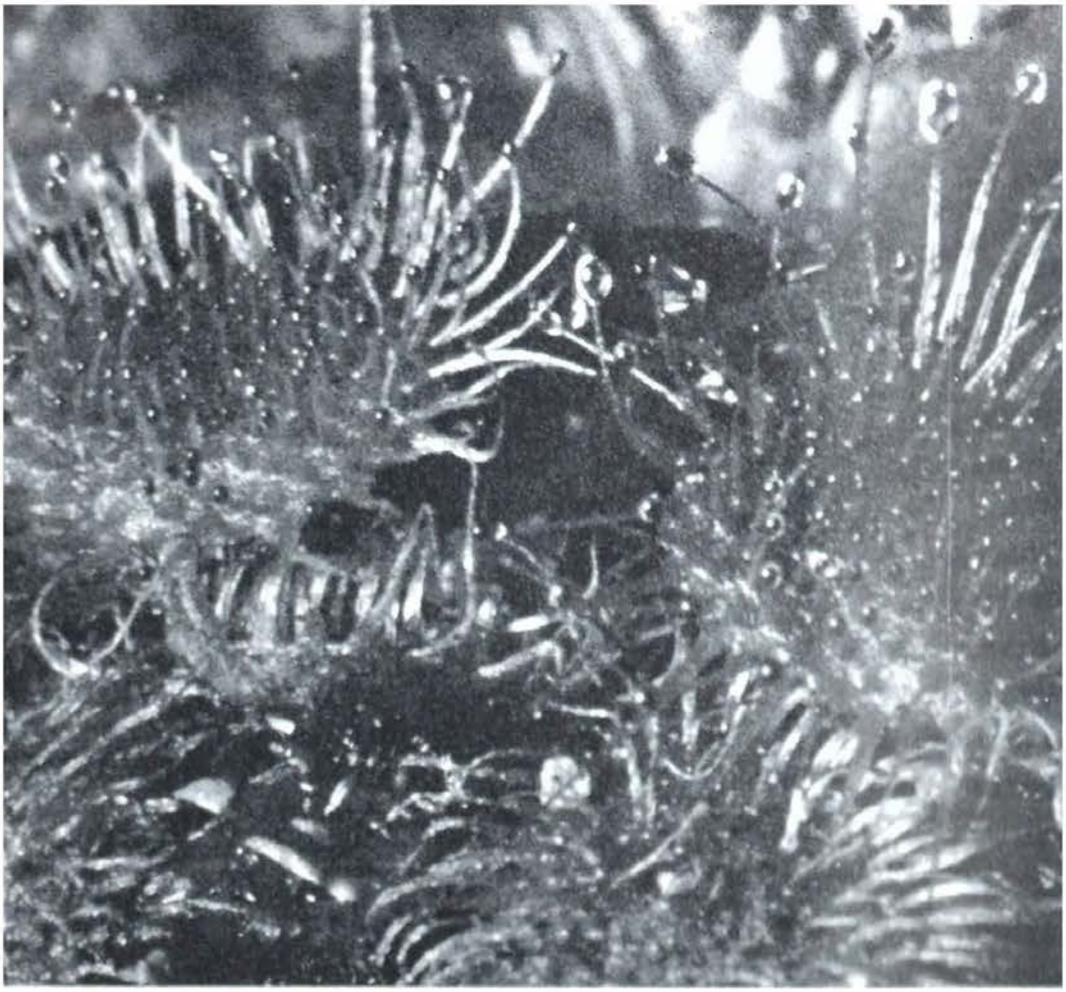
THE SUNDEW

The "fly-paper" type of insect catching plant is typified in the sundew *(Drosera rotundifolia)*. Its round leaves, less than a half-inch across, lie flat on the ground as the stalk of the plant is very short. These leaves are a beautiful deep red in color and are covered with gland-bearing tentacles which secrete great quantities of a sticky, viscous substance which competes very well with the material on flypaper for entangling flies. On the ends of the tentacles are drops of this substance which look like brightly glistening dewdrops. These bright drops, catching the light of the sun, and the round red leaves with their radiating tentacles, give rise to the common name, sundew.

Of the genus *Drosera* there are more than 90 species covering almost all parts of the world. The largest species occur in Australia, but others may be found elsewhere from South Africa to the high hills of the Andes. Invariably they are found in notoriously poor soils and they thrive under such conditions. The Sphagnum bog which is low in mineral salts is a typical habitat of *Drosera.*

Operation of the Sundew

The tentacles of the sundew are not merely static holders for the sticky substance, but have an unusual dynamic



The sundew *(Drosera ratundifolia)* is noted for its ability to catch insects by entangling them in the sticky, shiny glue-balls at the ends of the tentacles.

function as well. When a fly is entrapped in the sticky glue, the nearby tentacles begin slowly to bend over the prey until eventually they hold it down from the top. This may take a half-hour or so, the motion being too slow for the eye to follow directly, like the minute hand of a clock. However, through the medium of time-lapse photography the action can be seen for what it is, a graceful, deadly motion that results in a thorough demobilization of the insect as it is smothered in the secreted glue.

The sticky substance has a two-fold usefulness. Besides holding the insect by its stickiness, it is capable of dissolving animal material. As the arms bend over they press the

insect to the bosom of the plant where the gland-bearing arms are much shorter, and all of the octopus-like arms are brought into play. The leaf now acts as a stomach, and the sticky glue acts as pepsin acts in our own stomachs, digesting the soft parts of the insect. It takes several days to complete this digestion process after which the arms of the plant open up ready for another catch.

The Tentacles

The tentacles of the sundew have all of the elements of a leaf structure. Much research effort has gone into the study of these tenacles, and the more work that is done the more complicated they seem to be. In fact, the function of the tentacle is evidently much more complex than would be supposed from the relatively simple structure. The tentacle secretes mucilage drops, and the amount of this secretion varies with the demand, being great during capture and falling off after digestion of the prey. It also secretes the digestive enzymes which make the food of the captured insects available to the plant. It is also strongly suspected that an odoriferous lure is secreted. Water is also copiously secreted during early stages of digestion. As if this astounding array of secretions is not sufficient for one plant organ, the tentacles also absorb the food from the digested insects. These extremely complex functions are only partially understood, and time will undoubtedly shed more light on this problem.

As an insect becomes enmeshed in the sticky mucilage, its movement sends stimuli radially to the tentacles nearby. It takes but a little weight to induce a noticeable reaction. Darwin used a piece of human hair only 8/1000 of an inch in length and observed a reaction. As natural prey such as insects have motion associated with their capture, later experimenters have suggested that probably it was the

combination of this tiny bit of hair and the movement imparted to it by the normal vibration of the table which combined to create the stimulus. In any event, when one considers that this bit of hair weighed only about a millionth of a gram, the sensitivity of the sundew tentacle is amazing.

Movement

The mode of movement in the tentacle has also received the attention of some of the best botanical brains of the world during the past seventy-five years. It has been noted that the tentacles nearest the point of stimulation are the first to respond, all bending toward this spot. Slowly, the more distant ones enter into the fray until finally, if the stimulus is great and consistent enough, all of the tentacles and even the edges of the leaf itself will be curled over onto the trapped insect. Within 15 minutes the insect will be covered completely with the secretion, effectively smothering it. The tentacles bend toward the source of the stimulation, not necessarily toward the center of the leaf. Should the insect initiate the stimulation near one edge of the leaf, the tentacles incline in this direction.

The question that immediately presents itself is just how these tentacles move. They have no muscles. Observing the growth of plants through the medium of time-lapse photography we see the tortuous movements of stem and leaf during growth over a period of many days, but here is a movement which becomes noticeable within a matter of seconds and can bend a given tentacle through an arc of from 215 to 270 degrees in a few hours! It has been found that this tentacle movement, fast as it is, is also a growth phenomenon. In some as yet unknown way the stimulus from a given direction excites the growth of the cells on the opposite side of the tentacle causing it to bend toward the

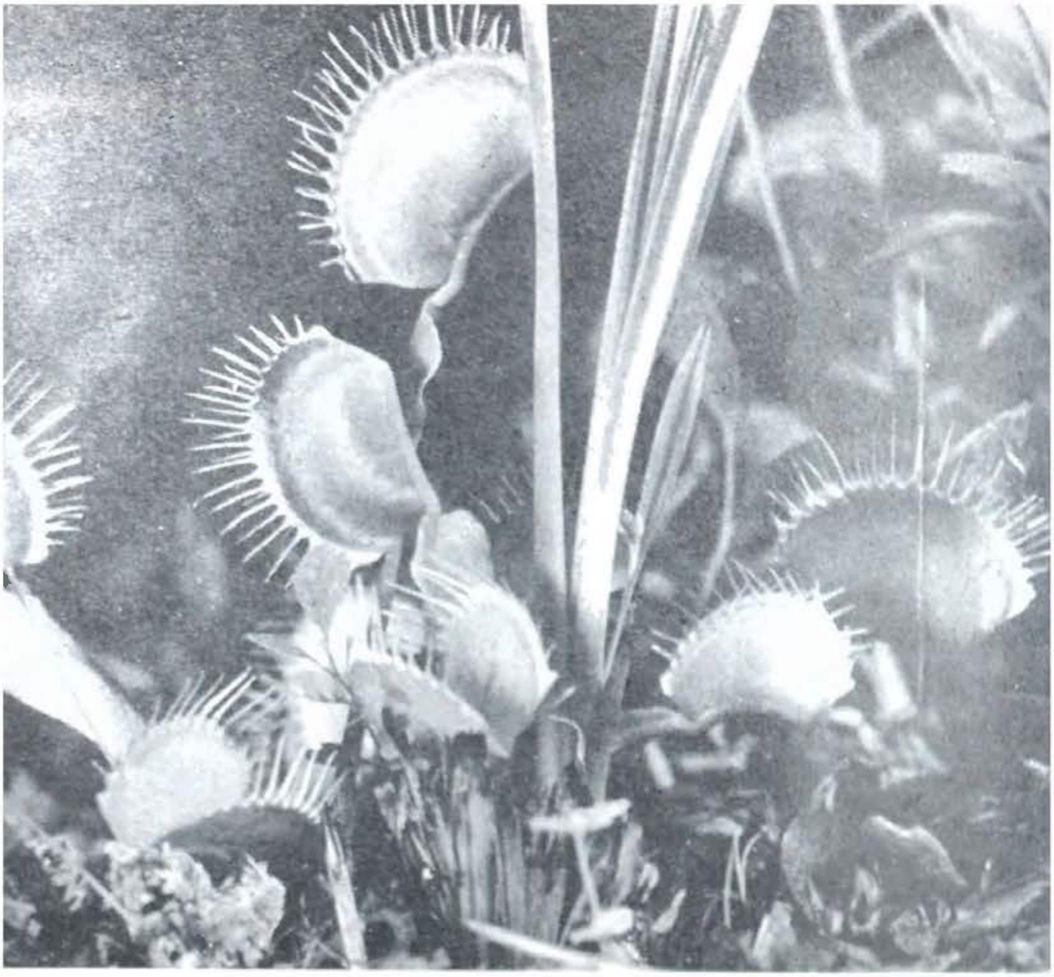
source of the stimulus. This growth starts at the base of the tentacle and progresses upward in a wave of activity. Four or five days after the insect is caught the digestion is completed and the tentacles unbend. If the stimulus is not of sufficient intensity or if it is of an unnatural character, the tentacle will unbend much sooner. This unbending is another growth phenomenon, this time on the opposite side of the tentacle. This limits the number of times a given tentacle can go through a bending and unbending cycle and it has been found that about three cycles is the limit. The leaf trap as a whole might catch many more than three insects because of the localization of effort, but for any one tentacle three cycles is about the maximum.

Necessity of Insect Food

It has been definitely established that sundew plants prosper more with insect food than without it, that the specialized traps serve a definite purpose in the life of the plant and are not just a freak of nature. Carefully controlled experiments have shown that plants that have insects in their diet produce more and bigger seeds and that the plants are larger. While the eating of insect food is not necessary for the continued growth of the plant, it does make for more flourishing existence.

VENUS'S-FLYTRAP

I should like to have seen the expression on that man's face! It was no less a personage than the Governor of the State of North Carolina, Arthur Dobbs, who made the discovery. In one of the many bogs of that state he had just found a most curious plant. As he wrote in a letter dated January 24, 1760, ". . . . the great wonder of the vegetable kingdom . . . to this surprising plant I have given the name Fly-Trap Sensitive." Governor Dobbs had



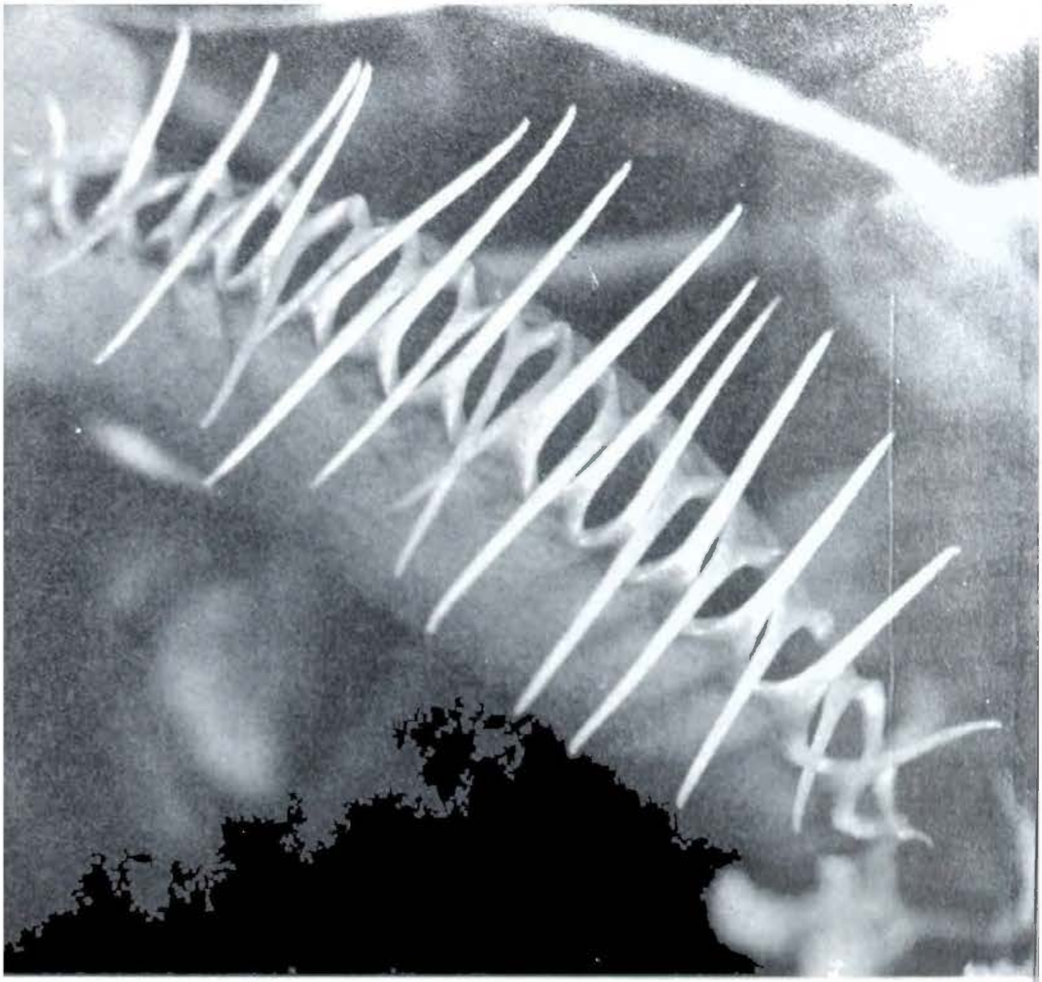
The Venus's-flytrap *(Dionaea muscipula)* most resembles man's crude bear trap.

just stumbled upon a truly great wonder of the vegetable kingdom, which is now known as Venus's-flytrap *(Dionaea muscipula)*, found in abundance in the eastern part of the Carolinas but nowhere else in the world.

Venus's-flytrap is a small plant having a rosette of leaves from 3 to 6 inches in diameter. These are the amazing parts of the plant, for the extremity of each leaf is modified into a perfect little two-lobed trap like "two upper eyelids joined at their bases" as M. A. Curtis described it in 1834. The traps, up to half an inch or more across, are formed by two dished lobes of more or less trapezoidal shape, hinged along one edge and armed with sharp spikes or teeth along the other edges. These ciliated edges of the

two lobes mesh accurately like the fingers of two hands clasped together. While in readiness for the catch, the two lobes are opened at an angle of from 40 to 50 degrees. A careful examination on the inner surface will disclose the presence of three tiny trigger hairs on each lobe arranged in a triangular configuration. When these hairs are touched by the visiting insect, the trap snaps shut locking the insect firmly within the prison house by the meshing of the spikes along the edges of the trap. The closure is a fast but partial one, and some time later the two halves of the trap clasp closely together and seal the doom of the insect prey within. This specialized leaf is first a trap, and then a stomach, for the insect is soon covered with secretions which break down the body tissues so that the plant can assimilate them for its own use. After about 10 days, the lobes of the trap separate and the dried chitinous remains of the insect visitor fall out. The trap is now ready for another catch and is fully capable of 2 or 3 such catches before the trap dies and gives way to other and more vigorous traps coming along. Curtis (1834) had the following to say of the effectiveness of this plant trap: "If it were a problem to construct a plant with reference to entrapping insects, I cannot conceive of a form and organization better adapted to secure that end than are found in *Dionaea muscipula.*" The scientific work of the last one hundred nineteen years has served only to show that this is a most conservative statement.

The trap is selective in its action. For example, if it is triggered by an insect, it will stay closed until the insect is thoroughly digested, which may be ten or more days. If accidentally triggered by a leaf or twig, the trap will shut but will open again very much sooner as if sensing its mistake.



The serrated edges of Venus's-flytrap hold the insect inside the trap.

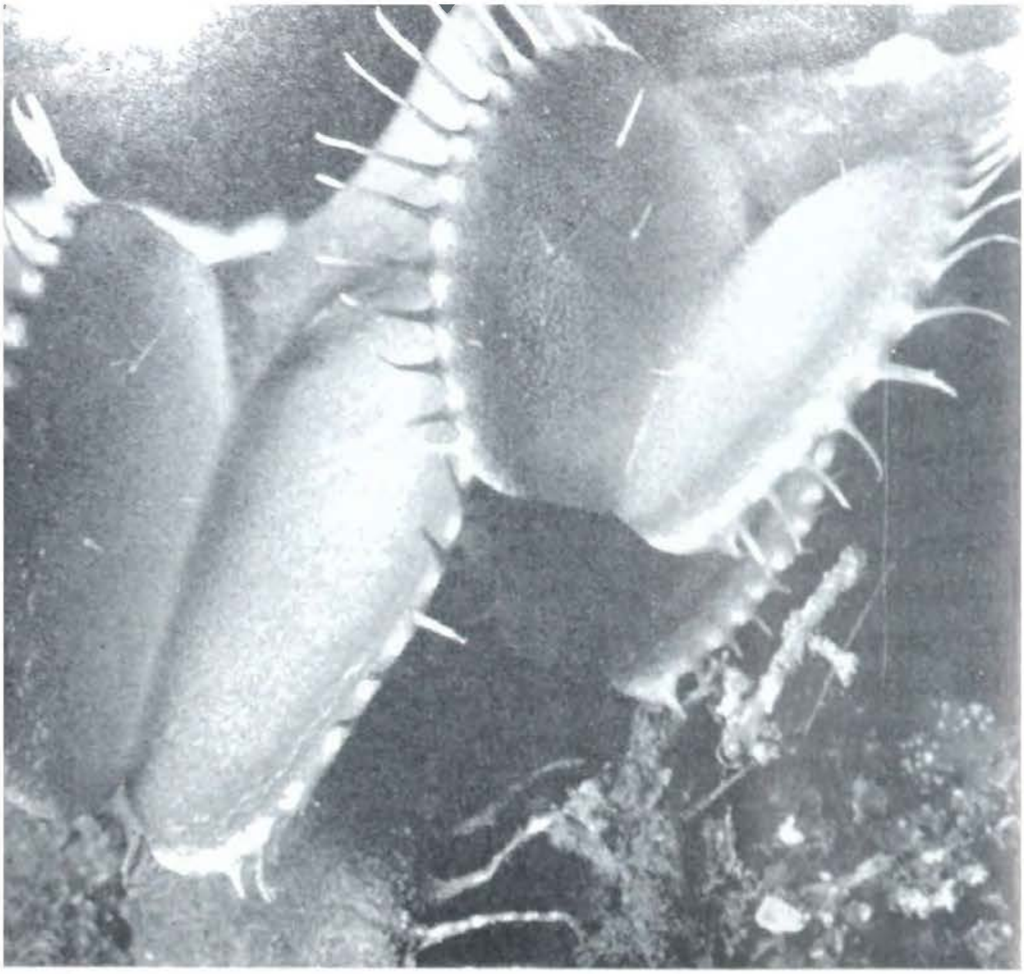
The Trap

The inner faces of the two lobes are rich in various types of glands. The alluring glands are restricted to a narrow band just within the ciliated edge of the lobes. These glands are embedded in the surface of the trap and contain no pigment. That these glands exude a substance which is very attractive to visiting insects is something that can be observed by anyone with a little patience. If the insects can be viewed with a magnifying glass, it can be seen that their mouth parts are busy lapping up the sticky substance which, in addition to a good taste, must also have a good aroma to account for the attraction of the trap for the insects.

In the central portion of the inner surface of each trap lobe are many other glands which, under the microscope, stand out prominently from the surface of the leaf. They are also colored a deep red so that the central region of the inner surface of the trap is of this color. These are the glands which secrete the digestive substances and also absorb the food from the insects. There is a remarkable relationship between the arrangement of these two groups of glands and the size of the insects caught. The insects which are too small to span the distance from the alluring glands along the ciliated margin of the trap to the area covered by the red digestive glands in the center of the trap face are not very likely to trip the trap. Insects of a length around ¼ inch are favored, and studies of the catches have borne out this conclusion. The arrangement and functioning of the sensitive hairs bear on this, and will be discussed further at a later time.

Movement

Careful study of *Dionaea* has been directed toward the problem of just what causes the movement. A comparison of the traps of the related *Aldrovanda* (an aquatic plant having traps made of a single course of cells), the immature traps of *Dionaea* having walls a few courses of cells thick, and the mature *Dionaea* traps having walls made up of many cell courses, indicated that the mechanics of the movement of the trap was not within the wall of the lobes. It has been concluded that the seat of the movement is in the epidermis, the thin skinlike layer of cells covering the faces of the lobes. All of the movement is confined in the lobes as there is no true hinge action. The region where one lobe joins the other, known as the midrib, has no articulation such as we see in a hinge. Much research effort has been expended in trying to solve the mechanism



The opened Venus's-flytrap showing the three trigger hairs on each leaf of the trap.

of the trap closure in *Dionaea,* but as yet there is n
definite answer. Water movements from one group o
cells to another have been suggested. For example, wat
from cells along the inner face flowing to cells along th
outer face could cause the expansion of the one and co
traction of the other with a resultant bending of the lob
Chemical changes within the leaf changing sugar to star
in the inner surfaces of the trap lobes have also bee
postulated, but such rapid chemical changes are not know
for the closure of the trap can be accomplished in as litt
as ½ second. In some unknown way tensions are built u
which are suddenly released by the triggering action of th
sensitive hairs.

Sensitive Hairs

In 1770 Ellis thought the three delicate hairs on each lobe of the trap were for the purpose of impaling the insect as the trap closed. In 1834 Curtis expressed his conviction that the hairs possessed a sensitivity resident within themselves. The closure of the traps was thought by many to be a periodic action without reference to such things as a triggering effect. The trap was supposed to catch any insects unfortunate enough to be inside at the moment of closure and it was thought that the traps opened at night. A number of experimental researchers soon showed, however, that the closure was definitely tied in with the stimulation of the three minute hairs on each leaf of the trap.

Under microscopic examination the trigger "hair" is revealed to be a slender cone about 1/16 inch high with a base diameter a tenth the height. The cone is supported on a short pedestal which has a course of deeply grooved cells entirely around the base. As the hair is touched, it acts as a lever resulting in a great deformation of this groove.

The trigger action of *Dionaea* traps is more complicated than the simple closure when a hair is touched. While the picture is complicated by a number of things such as temperature and the physiological condition of the trap, it appears that a summation of stimuli is needed to trip the trap. One trigger hair touched twice or two hairs touched once each with a time interval between stimuli of from about one second to 20 seconds is necessary for tripping. At least two stimuli are required at temperatures about 15° centigrade. The sensitivity of the plant increases as the temperature increases, and half the time only one stimulus is needed at 40° C. Of this it can be certain, however, the response follows a certain definite amount of accumulated

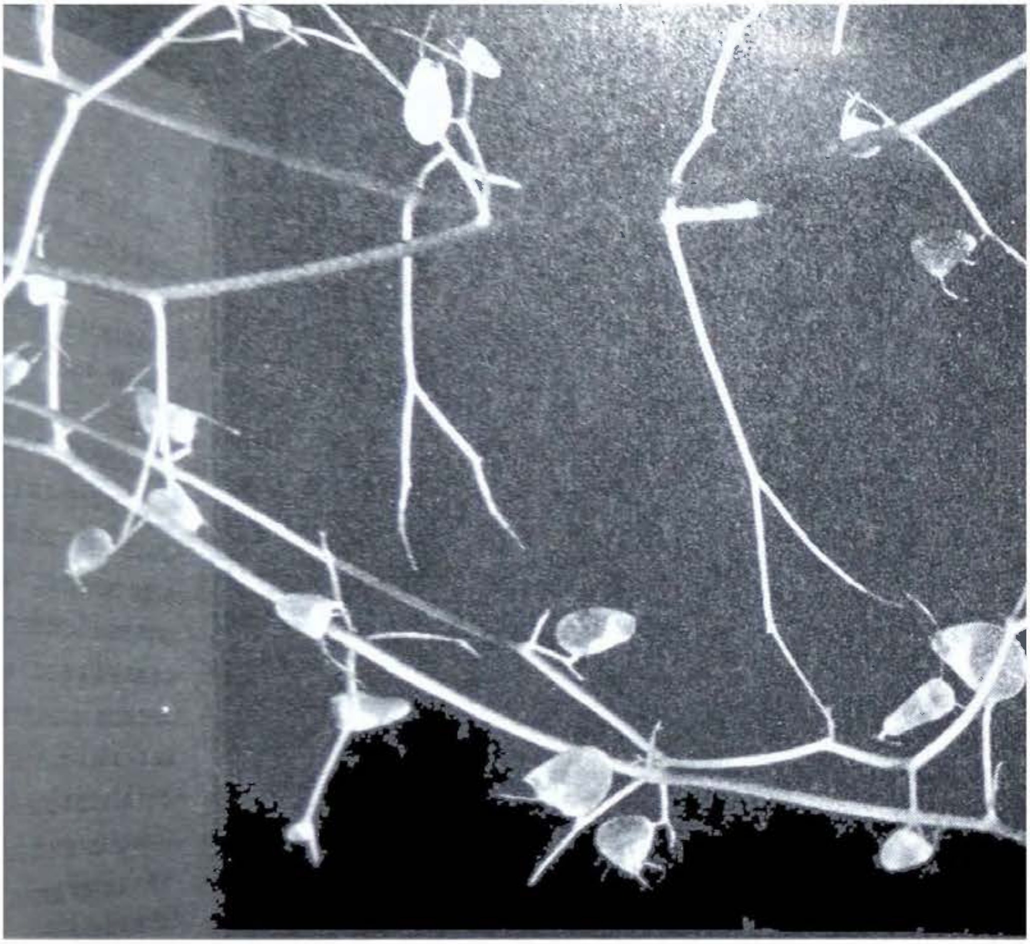
stimulation. It is thought that this also contributes to the sorting action the traps seem to exhibit, discriminating against the smaller insects which would hardly make a closure worth while as far as food value is concerned, and the larger insects which the trap would not be able to hold.

Electrical Currents

The modern neurologist must be something of an electronics expert, for the nerve signals he studies are feeble electrical currents. The motor muscles of the human body, for example, are stimulated to action by an electrical signal sent from the brain. The Venus's-flytrap tissue is not muscle tissue, but as long ago as 1873 it was known that actuating the trigger hairs caused electrical disturbances across the leaf of the trap. Recently (1950) Stuhlman and Darden of the Department of Physics of the University of North Carolina applied some of the modern neurological "know-how" to the study of the currents of the traps. By placing two special nonpolarizing electrodes on the under side of the trap, they recorded surges of electricity as trigger hairs were bent with a fine glass hook. In the space of 1/10 second this electrical transient rose to its maximum value and then decayed, settling down in about 1.5 seconds. The true significance of this electrical current flow is not known but would seem to indicate that the complexity of the operation of the trap is far greater than we suspect at this time.

Digestion

No odor accompanies the digestion of the insects within the traps of *Dionaea,* indicating that bacterial action plays little or no part in their breakdown. It is known that when a piece of meat is placed partly within and partly outside the trap, putrefaction results on the part outside, but not inside the trap. Placing the rotted portion inside another



The bladderwort (*Utricularia vulgaris*) is an aquatic plant which floats in the water. The bulbous growths, about the size of the head of a pin, are traps which capture protozoa and other aquatic animals.

[illegible] causes the smell to disappear. Placing a piece of food within the trap and cutting it open after about two days shows the extent of the secretion, for drops of it ooze from the trap. While there have been no definite experiments which divulge the nature of the digestion in Venus's-flytrap, there seems to be no question that such takes place.

BLADDERWORTS

When one has become accustomed to the rather unusual situation that we find in the world — that there are many kinds of plants that eat animals — he will not be so surprised to learn that the same situation exists in the microscopic and submicroscopic world. We shall principally

consider only one of the 265 species of Utricularia, *Utricularia vulgaris,* one of the most commonly occurring carnivorous plants. It is found in ponds around the world, in North America, Europe, and Asia, although it has not yet been discovered on oceanic islands.

The common bladderwort is a freely floating aquatic plant of several feet in extent. It is lax in the water and becomes quite a tangled mass of interlocking stems. Frequently it grows entangled with other plants. It is entirely rootless during all of its stages. There is little distinction between the stem and the leaf, but growing from the stems are tiny light-colored bulbs. These are the traps which have amazed the scientific world by their complexity and deadly efficiency. The name of these plants comes from "utriculus" a small bottle of skin or leather having yielding sides and stopper, a description aptly applying to these traps as we shall see.

All of the *Utricularia* representatives are found in still-water except a couple of species found in South America and Africa which grow in running water attached to the rocks on the bottom of the stream. It is interesting to note that these traps are nicely streamlined. The bladderworts may be frozen in the pond without danger of being killed out, as the tips give rise to new plants in the spring.

The Utricularia traps vary in size from 0.3 to 5 or 6 mm. in length, U. *vulgaria* being of average size about 2 or 3 mm. in length. In other words, the trap is just about the size of a pin head. It would be technically improper to call this trap microscopic in size, but it is certainly true that one cannot appreciate the intricate nature of these exquisite traps without a good microscope.

These traps are flattened, pear-shaped, hollow bodies attached to the stem of the plant by a short stalk. At the

Glass model of *Utricularia* showing numerous captured animals within the trap. (American Museum of Natural History)

end of the trap opposite to the attachments, there is an opening, or mouth, which opens into the hollow cavity inside. At the edge of this doorway there are two branched whiskers similar in appearance to the antennae of insects. Beneath these, attached to the door closing the opening, are several short bristles which are the trigger hairs of this delicately balanced mechanism. A water animal such as a water-flea *(daphnia)* or an ostracod swims around in its apparently aimless fashion until, aided by the funneling action of the converging "guide" whiskers, it touches the triggering bristles. At this instant the door flies open and the hapless animal is sucked violently through the door and engulfed within the trap. In taking motion pictures of this phenomenon, we have observed that in one frame the trigger bristles are touched, and in the next frame the animal is deep in the inner recesses of the trap. The water flea or other animal swimming innocently about the *Utricularia* trap is transformed in the space of 1/50 second from freedom to its doom within the trap. Doom is just the word, for the traps are actually the "stomachs" of the plant where the entrapped animals are digested and utilized as food. The study of this fascinating organism has been the consuming interest of scores of top-flight scientists during the past hundred years. This study has been a case history of the scientific method in action, complete with wild guessing and incorrect and premature conclusions on the one hand and incontrovertible demonstrations and careful, painstaking work on the other. It has also shown clearly that the advances of one generation are rooted firmly in the findings of the past.

The Purpose of the Traps

The conciseness of the statement that these pear-shaped bodies capture and digest prey sounds very simple. Thrust-

ing aside the obvious advantages of hindsight for the moment, let us trace some of the more outstanding developments in the unfolding of knowledge on *Utricularia.*

Some of the earliest records on the *Utricularia* plants state the conviction that the bladders were air reservoirs which supplied air to the plants. Still others thought they were air bladders for the purpose of making the plant float. This latter theory was thoroughly exploded when an investigator cut off all the bladders and found that the plant still floated nicely. It is now known that the traps contain no air under natural conditions and it is of interest to see how so many people for so many years came up with the same error. The triggering bristles are so sensitive in their action that if a plant is raised from the water (the first normal action of the would-be investigator) the surface tension of the water film is strong enough to trip the traps, causing them to suck in a mouthful of air.

From the book before me, *Marvels of Plant Life* by Daglish, there is the following statement concerning the *Utricularia* trap:

> Small aquatic creatures swimming about near the plant, and finding these little chambers inviting exploration, not infrequently enter, only to have their retreat immediately cut off by the closing of the elastic valve. In this cell, despite its efforts to escape, the prisoner is shortly done to death, the plant profiting by the products of its disintegrating body.

This book was published in 1924, but it echoes a misconception prevalent to this day which started a long time ago. This error is that the door of the Utricularia is a passive flap which allows creatures to enter, but which swings down and prevents them from leaving. In 1873, Mrs. Mary Treat found some entomostraca in a trap and agreed with

other authorities that they just pushed the door open and walked in. Three years later, however, she had reason to doubt the soundness of this conclusion, for one day while she was watching a trap, she saw the approaching prey suddenly engulfed — so fast that her eye could not follow. As she put it, it was drawn in as though by a "partial vacuum." How right she was she had no way of knowing at the time, for she could find no mechanism for the production of a partial vacuum, not noting the deformation of the walls. Mrs. Treat's new ideas were not shared by her contemporaries; for example, just about this same time Charles Darwin wrote, ". . . . animals enter merely by forcing their way through the slit-like orifice; their heads serving as a wedge." Goebel, Meierhofer, Leutzelburg, and Cohn were also among the authorities holding this view, in fact Cohn published a drawing of the *Utricularia vulgaris* trap which is still used today, incorrect as it is.

As is frequently the case, an outsider with the temerity to question the findings of science, broke the case wide open. In 1911 Frank Brocher, not even a botanist, pointed out correctly that the explanation that had been so freely propagated for many years was only an hypothesis as no one had ever seen an animal gain entrance to a trap by nudging its head under the door. Brocher, even as Darwin and others, noted that occasionally the prey mysteriously disappeared. He further noted that there was a spasmodic jerk of the trap when this happened and that it thickened a bit. He even went so far as to excite this spasm by touching the area near the mouth of the trap with a needle point. Although he still had no good explanation for the trapping, he was sure that the prey didn't just walk in. How about the tiny fishes that were caught by the tail? Were they trying to back into the trap?

Ekambaram, a researcher in India, became intrigued by the problem and found that by pressing on the sides he was able to reset the trap after it had been sprung, but apparently he was unaware that the plant was able to reset itself. The hairs were recognized for what they are, however, triggers which, when hit by wandering beasties, initiate a sudden action which sweeps the beastie inside the trap.

Francis E. Lloyd, an outstanding botanist who but recently passed from the scene, was the first one to assemble all the great mass of information on carnivorous plants, devoting years to the study of the Utricularia trap. The detailed description of the operation and construction of the traps to follow is based, in large measure, upon his patient work in compilation and research. Lloyd said, concerning these traps, "But most to be wondered at are the traps which present an outstanding degree of mechanical delicacy depending on a fineness of structure scarcely equalled elsewhere in the plant kingdom."

The Traps

The individual traps, about the size of the head of a pin, are shaped much like flattened spheres modified somewhat at the point of attachment and also at the mouth. The wall of the trap is composed of two layers of cells, like a brick wall two bricks thick. The outer and the inner surfaces of this wall are covered by a thin cuticle. The thickness of the wall varies from place to place, and is closely related to the deflections of the sides of the trap. Chlorophyll bodies are present throughout the plant, including the traps, somewhat more on the outer course of the cells of the walls than on the inner. On the inside of the trap there are short cell-columns capped by odd two-leafed or four-leafed capitals which are generally regarded as the organs which secrete the ferments and acid necessary for digestion and

also do the absorbing of the nutriment from the trapped animals.

The sides of the trap are slightly concave while the trap is set, and this changes to a slight outward curvature when the trap is sprung. Over the outer surface of the trap are scattered small spherical glands which secrete mucilage, in fact, similar glands do the same thing over the whole plant surface. Stalked glands around the mouth exude mucilage and sugar said by some to provide a lure for the prey.

The Antennae

The edge of the mouth of the trap carries a pair of branched antennae which tend to guide the prey to the mouth of the trap. Authorities seem to agree that in the water species of Utricularia this guiding is the sole function of the antennae, much like a funnel-like fence at the entrance of a cattle corral. In certain mud-dwelling species, however, it is felt that probably they keep the debris from choking the entrance to the mouth. In species that live in wet, sandy soils, the antennae probably assist in attracting capillary water in which the prey swims.

Trigger Hairs

Along the lower lip of the door of *Utricularia vulgaris* there are four stiff, tapering bristles which extend outward, curving gently upward. Each bristle is composed of 3 to 5 cells, the one at the base being quite stubby, and the outer one long and tapered. These hairs are not sensory organs in any way, but are rather very delicate levers which distort the lower edge of the door when touched. This upsets the delicate balance of forces in unstable equilibrium, resulting in the sudden surge of water sweeping into the trap. Scientists have killed these bristles with iodine and their mechanical function of tripping the trap was not impaired.

Their mechanical arrangement is such that a downward pressure more readily trips the trap than a sideways or upward motion.

The Door

Early in the work, it was thought that the Utricularia door was a simple flexible flap, much like the valves in our blood vessels. Further study revealed that the door was instead a very complex mechanism. Meierhofer, upon pondering the mechanism of the door, exclaimed that it was a "most wonderful" arrangement, a typical bit of scientific understatement. The door is also two cells thick, but the depth of the cells (and thus the thickness of the door) and the placement of constrictions in the cell walls are arranged for extreme flexibility where a hinging section is needed, or for rigidity. The door is actually composed of two parts, the larger upper main part, and the lower "velum" which acts much like the weatherstripping under the door, filling the space between the main door and the threshhold. This seal is made perfect by the presence of mucilage along the lip.

Water is pumped through the membranes of the trap walls which result in a lowering of the pressure within the trap and the inward deflection of the sides of the trap. As water is fed out through the walls of the cells a partial vacuum is built up inside. The door both slopes and opens inwardly, and the engineer peers at it in wonder as a first glance would seem to indicate that the greater pressure of the water outside the trap would most certainly result in a steady leakage. However, a careful analysis of the forces acting at the point of contact of the lip of the door and the threshold of the floor shows that the door really can withstand the pressure of the water until the trigger hair

is touched. The lower lip of the door is yielding so that it can make a hermetic seal. Ethylene blue dye placed in the water does not penetrate the door to the lower pressure region within. It has been found that a very small hair placed under the door makes the trap completely inoperative because the pressure cannot be built up inside due to the leakage under the door. If there is a good seal the walls of the trap are sucked in under stress as the pressure is reduced inside and it is this stress that provides the sucking power when the door is "cracked" a bit. A comparable example is the case of the airplane flying at great altitudes with the cabin pressurized. When a window or an astrodome breaks, the person nearby is likely to be projected out of the plane much as the animalcule is plunged into the depths of the *Utricularia* trap from a high pressure to a low pressure region. The trigger bristles are levers which open the bottom of the door slightly to start the reaction, the door then flying out of the way and again returning to seal the opening.

It sometimes happens that prey too large for the trap to handle triggers the hairs. Tiny tadpoles imported to control a certain insect pest in sugar cane in Queensland tripped many *Utricularia* traps. Large prey of this type, if of a soft and pliable form, may be only partially engulfed at first, but makes such a good seal at the door that the trap is able to reduce pressure within by its pumping out of water through the walls. This continual sucking may eventually pull the entire tadpole into the trap. A mosquito larva has been observed caught by the tail and partially engulfed. Three days later only the head, too big to go through the door, protruded. Incidentally, 10 days later the trap died, apparently from over-eating! Shreds of albumen (white of egg cooked in hot water), too long to be entirely taken in

on the first spasm, are sucked completely in in a matter of minutes. Accidentally trapping a too-large prey of a stiff and unyielding kind makes the trap inoperative. The resetting of the trap varies among the species; some resetting in from 15 minutes to half an hour, and others taking as much as two hours. *Utricularia vulgaris* takes about one half hour.

Digestion

About 1876, Mrs. Treat reported that larvae were digested in about 48 hours in *Utricularia vulgaris* bladders. She said, "I was forced to the conclusion that these little bladders are in truth like so many stomachs, digesting and assimilating animal food." Actually what was noted was that the animals within the traps disintegrated, the digestion was inferred. The problem was complicated by the fact that no one reported any odor of putrefaction so noticeable in the pitcher plant. Bacteria did not seem to grow in the traps. Were there digestive ferments to be found inside the trap? Darwin's experiments with bits of meat, albumen, and cartilage gave negative results. Leutzelburg in 1910 ground up traps and made an extract by pressing them but failed to solve the problem. More recently, Kiesel's work calls attention to the possibility of an important role for microorganisms in the digestion of food. The problem is still not solved, and much more work remains before it can be said with any degree of certainty just what process the plant utilizes in getting the nutrients from the bodies of the captured prey. There seems to be no doubt that all the prey engulfed eventually dies and is digested, except a few such as *Euglena, Heteronama, Phacus,* and probably diatoms and desmids — all of which seem to thrive within their utricularian prison-house.

> In closing this account one cannot but wonder at th astonishing variety of trap structure. It is not les astonishing that there is no evidence that one form o trap is superior to another in action. The fact of variet is one with the same phenomenon observed when w survey attentively some other unit of structure. It seem as though nature, or to deify her fruitfulness, "Nature,' is not nor ever has been content to make some one thing however satisfactory, and to let it go at that. She mus show that she is not bound to the details of a patterr that, in this case, she can make a whole shelf full o different kinds of traps, as if to puzzle you to pick u the best. (Lloyd).

With this appreciation of the traps God has made in the plant kingdom, the bear trap looks strangely cold anc ineffective! True, it is larger than Venus's-flytrap, anc quite similar in appearance, but is it better? The flytrap's lures, its special combination trigger, its electrically operatec release system, and its self-resetting mechanism, none o which are even understood by man, incline one to believe that man's traps cannot be compared to such a delicate mechanism. A similar inspection of man's pitfalls anc flypaper and a comparison to the pitcher plants and the sundew only piles evidence upon evidence on an already airtight case. What pitfall of man's has a lure irresistible to the prey or what flypaper curls over the fly and digests it?

We see that the workmanship of the Creator is so extravagant in its variety, so intricate in its form, so efficien in its operation that the products of man's hands are as nothing.

Chapter 3

NATURE HAD THE FIRST DOORS

A DOOR SEEMS TO BE just about the most straightforward mechanical contrivance one could possibly imagine. hey are such ridiculously simple objects that although we re completely surrounded by all sorts of doors, we are arcely aware of them. Perhaps we give them a passing ncomplimentary thought as we fumble for a key in the ark or breathe a sigh of gratitude as we close out the orm, but usually we use them unconscious of the very al part doors play in our lives. Doors are the very epitome f the democratic doctrine that a man's home is his castle, f the right to privacy, of the ownership of private prop-rty. Open doors are the token of gracious welcome, closed oors of forbidding exclusion. There are immigration oors to our country, gates to our cities, doors to our homes, oors between rooms in the home, doors to closets, doors n cupboards and cabinets within the closets. When we ome right down to considering the tremendous part that oors play in our lives, we marvel that they are accorded o little of our voluntary attention.

And yet someone had to be the first to devise the first oor. As simple as the problem of inventing this first door ow appears to us, someone at some time in the dim past pplied intelligence and obtained the answer which has ranched out to the varied forms of doors that we see

Can you spot the trapdoor spider houses in this picture? This spider camouflages the entrance to its house so carefully that it is extremely difficult to find.

This is a view of the same area covered in photograph on the opposite page except that the trapdoor spider doors are opened.

today. There was some man that devised what he thought was the first door, but whether he knew it or not, the principle of the door was in existence before man appeared on this earth. The inventor, God Himself; the craftsman, the trapdoor spider! The descendants of this sturdy craftsman are still busily at work fashioning some of the finest and most effective doors known to man.

THE CALIFORNIA TRAPDOOR SPIDER

There are over twenty species of trapdoor spiders in America, mostly in the southern United States. The local species readily available happened to be the California trapdoor spider, *Bothriocyrtum californicum*. This is a large spider, about an inch across. As it is one of the tarantulas the large size is not surprising. This group of spiders was named after the town of Tarento in southern Italy and the name is steeped in superstition and folklore for the bite of these spiders was supposed to cause violent sickness and insanity which was assuaged only by music. The victim danced wildly to the music and eventually recovered, much to the relief of the customers who paid good money to see the performance. It is surprising how much of this distorted view persists to this day, although the tarantula bite hurts only because it is a big spider and can nip hard, the venom having only a slight effect on man. The California trapdoor spider is small as tarantulas go and his size of approximately an inch across is small compared to a South American cousin that measures ten inches across fully extended legs!

The trapdoor spider of California has a nearly oval, black cephalothorax and legs, and the abdomen is a dark brown. His hairs are few and short, especially compared to his shaggy relatives. This spider is a hermit and loves solitude, and the outstanding characteristic is that he builds himself

a tunnel with a beautifully wrought door with a silk hinge closing the opening of the tunnel. This burrow is usually 5 to 8 inches in depth, and the diameter varies with the size of the spider, but always of sufficient size to allow it to turn around in the tunnel. Because it lives for a number of years, the house has to be periodically enlarged to accommodate its growth. This has a fascinating parallel in the molting process of spiders. The hard outer skeleton is not flexible enough to allow growth, so the spider has to cast off the old skeleton from time to time and grow a new one of larger size. So it is with the trapdoor spider's house, it too must be enlarged from time to time to accommodate the growth of the spider.

The lid to the trapdoor spider's home is a skillfully constructed device and is so shaped that the edges fit very tightly into the hole, much like an automobile valve carefully fitted into the valve seat. The spider's normal position in the burrow is just beneath the door holding on to the edge of the door with its tarsal claws. Its body is wedged against the sides of the hole apparently, for otherwise scientists have difficulty in accounting for the great strength with which it is able to resist the opening of the door by an outsider. Passmore estimated that it took a force of about ten pounds to open the door against the efforts of the spider. Van Riper actually measured the force required to open the door against the wishes of the spider and found that it required 14 ounces. The latter is 140 times the weight of the spider which is comparable to a 150-pound man resisting a pull of 10 tons!

This spider is a nocturnal creature and sometimes forages for food at night. Much of his hunting can be done right from his front door, however, for the trapdoor spider has a very keen tactile sense. His eyesight is poor, but he

apparently can hear the footsteps of his insect prey for a considerable distance. An insect placed near the firmly closed door will suddenly be grabbed by the spider as it springs out like a jack-in-the-box. At the Moody Institute of Science, motion pictures of the trapdoor spider popping out of its hole and grabbing the insect prey have been obtained. To obtain these, sowbugs were placed in the vicinity of the door of the burrow. These bugs would start to meander around and when they approached a spot about an inch from the door, the camera was started and the spider popped out, pounced on the hapless insect and dragged it into the burrow. With experience, one could usually predict the instant the spider would emerge, but the action is so fast that once the spider was seen there was no chance to start the camera before the door was closed and the show was over.

Almost as amazing as the construction of the door itself is the uncanny way the spider, clinging beneath the tightly closed door, seems to know just where the sowbug is all the time. When the door flies open, the trapdoor spider dives directly at the prey and no time is lost in getting bearings. Apparently the spider "hears" the feeble vibrations of the earth as the sowbug crawls about and by some system of triangulation as yet unknown is able to determine its exact position.

The spider has one thing to watch in this kind of hunting: it always seeks to keep the rear of its abdomen or at least its hind legs in the doorway so that it can readily haul its prey down into the dark of its tunnel. If it were to allow the door to close behind it, it would have difficulty in raising it again, for the door fits so snugly that it is only with much scratching that the spider can insert its claws and obtain sufficient purchase to reopen the door.

The California trapdoor spider builds one of the finest doors of any of the trapdoor spiders. It actually fits so tightly with its beveled edge that it is practically gastight. Grassfires sweep over the hills frequented by these spiders without any harm to the inhabitants of the subterranean burrows. This type of door is called the "cork-type" door because of its snug, beveled fit.

There are other kinds of doors that are made by other species of spiders. For example, *Myrmekiaphila* and *Actinoxia* construct a floppy silken door that seems to serve more as a camouflage for the tunnel opening than anything else. These spiders also construct side tunnels running off from the main one, and at each intersection another door is carefully constructed. Thus in case of attack, these spiders have two lines of defense. *Cyclocosmia Truncata* also has a unique way of throwing up defenses against intruders. Its abdomen is formed into a flat disk with a very tough, leathery behind. About two-thirds of the way down the tunnel there is a constriction and when threatened this spider retreats until he reaches the narrowed portion. Here his abdomen tightly plugs the passage way, presenting the leathery plug to the enemy. The amazing thing is that this elaborate arrangement is the second line of defense, for this spider has a surface door.

To a spider like the trapdoor spider whose senses are not as sharp as those of some of his enemies, the advantages of living in a tunnel closed by a trapdoor are quite obvious. Certainly it doesn't have to worry about being attacked from the rear while down in such a hole. The natural camouflage of the door is of great value in hiding the entrance. The spider places bits of moss and tiny sticks on the top of the door which makes it blend beautifully

The trapdoor spider in her silk-lined home. Normally the spider is positioned just below the door, ready to spring out on luscious insects passing by.

with the surroundings. Frequently seeds are planted on the door, intentionally or otherwise, and the sprouts of grass or moss contribute to the camouflage. No one knows so well how these entrances are camouflaged as the person who goes out to find some.

A well-fitted trapdoor is also fine protection against the weather. The sites are so selected that the drainage is good and in such spots the water runs right over the door without penetrating the hole. Of course, a house built in the dirt this way would have the advantage of being cool in the summer and warm in the winter due to the great thermal inertia of the earth.

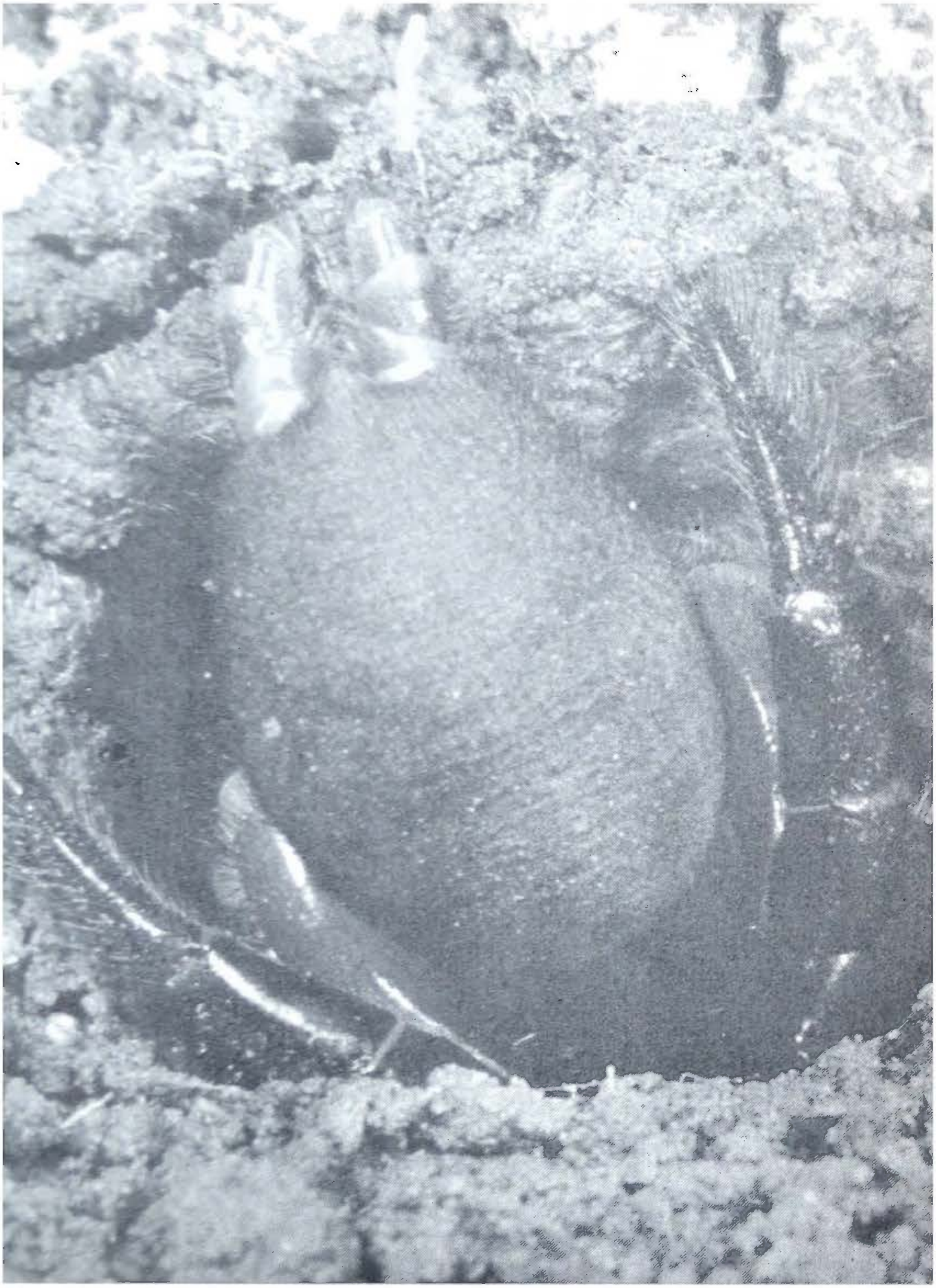
LIFE CYCLE

The female spider lives alone in the burrow with a silk and earth plug stopping the entrance until her eggs hatch in the spring. The babies stay within the confines of the burrow until they are old enough to go off on their own. At this time the plug is broken and they spread out and build tiny replicas of mother's home, the greater the dispersion the better as far as maintenance of the species is concerned. During the late summer the adult spider again seals her burrow with a smooth plug of earth and carries on the serious business of molting. Little is known of the male of the California trapdoor spider other than that he builds a separate, smaller tunnel.

CONSTRUCTION OF THE BURROW

If a trapdoor spider is taken out of her own home and placed on some fresh dirt in a box she may start the construction of a new home before one's eyes. This fascinating procedure starts with the excavation of a small depression. The comb-like rake of spines on the jaws of the spider come into play in this operation. As soon as the depression

The early stages of building the home of the trapdoor spider.



The South end of a Northbound trapdoor spider showing spinnerets applying a coating of silk to the underside of the door.

The trapdoor spider dashes out of her burrow to capture a sowbug. Note that she is very careful to keep her abdomen in the doorway.

is large enough to accommodate the bulk of the spider, construction of the door is started. Material is added a pellet at a time, accompanied by much chewing alternating with the depositing of silk from the spinnerets. These silk strand reinforcements within the earthen door account for its great strength and for the highly effective action of the hinge. After the door is shaped properly, work continues on the tunnel walls as they are compacted with a mixture of saliva, earth, and silk. However, the tunnel must go deeper, so excavation is resumed as a pellet of earth is forcibly thrown out every time the door pops open! After the walls and the door are thoroughly smoothed and water-

proofed by the chewing action, a fine coating of silk is applied. Besides acting as an effective lining, this silk provides foothold on the sides of the tunnel, and provides the anchorage by which the spider holds the door closed against intruders.

THE SPIDER WASP

Nature maintains her balance by providing an enemy for every organism, and the California trapdoor spider is no exception to this. It's nemesis is the spider wasp which, like other wasps, lives on the nectar of flowers, but for her babies this wasp must provide spider food. Although the wasp is only a tenth the bulk of the spider, she prefers the larger mature spiders. Even with this great apparent advantage of size the trapdoor spider is no match for the wasp. In an uncanny way the wasp scurries hither and thither over the ground until a trapdoor is finally found. It may be quite a difficult job for the wasp to raise the heavy door, but usually she is equal to it. If not, she will gnaw a hole through the door and slip into the darkness within, carrying the battle courageously to the spider. All this time the spider undoubtedly knows of the presence of the wasp because of its delicate sense of feeling. The battle is very unequal — and in favor of the wasp in spite of her small size. After a brief tussle, the wasp maneuvers into position to place its deadly sting in a certain sensitive spot of the spider, and the battle is over. The spider does not die, but remains paralyzed and totally helpless and inactive. The sting of the wasp does not affect the heart and other vital organs, and the spider is to all intents and purposes placed in the wasp's deep-freeze for six months. The wasp then lays an egg on the abdomen of the spider and her task is finished as far as this particular spider is concerned and her responsibilities are over for the young

larva that will hatch from the egg. Upon hatching, the larva begins to eat the spider, and continues to do so until it is ready to spin its cocoon. Jenks observed a wasp subdue forty spiders in just this way, laying an egg on the abdomen of each vanquished spider, and it was not until she tackled her forty-first spider that she met her match, for this spider killed her.

THE FIRST DOORS

Thus we see that the first doors made by man were not the first expression of the door principle. The earthen door of the trapdoor spider was the prototype of all our doors today. Not only is the principle of the door clearly expounded by this lowly creature, but the beauty of its workmanship demands our highest admiration. No rough hewn door this, but a work of art in its symmetry and in its silk-surfaced beauty and a structural marvel to make the engineer of today take notice of the way this marvelous little builder takes the raw materials of dirt, saliva, and silk and fashions them into a structure so strong and effective and to such close tolerances.

Nature had it first? Yes, but in this close examination of the trapdoor spider's burrow and door we see something beyond the cold use of the word "nature" which embraces the world about us. Intelligence has been lavished upon the fashioning of the trapdoor spider's door and I am loath to give the spider all the credit. Behind the spider there is the guiding hand of God the Creator to whom must be granted the prior claim for another invention.

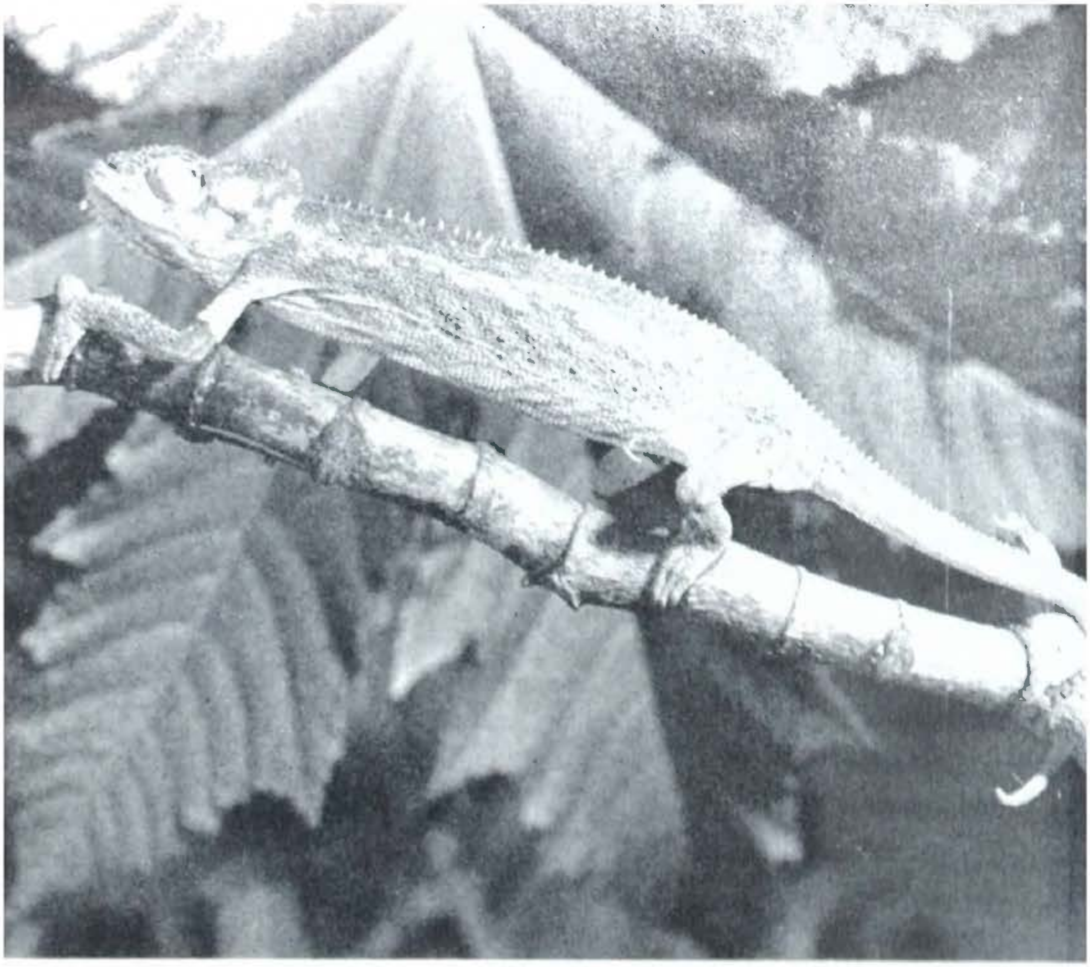
Chapter 4

THE AMAZING CHAMELEON

THE EXCITEMENT OF THE RODEO was everywhere. Youngsters in levis and ten-gallon hats perched atop the corral fence. Indians who had whizzed over from the reservation in large shiny automobiles sat impassively in front of painted canvas wigwams in their beaded buckskins and colorful feathers. Leathery cowhands in form-fitting, faded denim eyed their sallow city-bred imitators and their immaculate finery with an amused grin. All gave attention as the announcement of the calf-roping event blared from the loudspeaker.

The first contestant astride a wiry gray horse shot from the chute on the heels of a calf that was staking everything on picking them up and laying them down as fast as possible. However, the short legs of the calf were no match for the horse as the distance closed sufficiently for the cowboy to throw his lariat neatly over the neck of the calf. Knowing his part like an expert, the horse kept the rope taut while the rider leaped from the saddle, landed running, threw the calf and lashed its feet together. The stopwatch of the timekeeper was punched as the cowboy tossed both hands into the air signalling that the calf was conquered.

This is but a sideshow application of the faithful and useful lariat which has been such a valuable tool in the building of the West. The pioneer cattleman was clever and skilled in the use of the lariat. It was used to catch



Adult chameleon progressing along a limb showing its amazing features of ball-turret eyes, prehensile tail, divided feet, and strange dinosaur-like appearance.

his saddle horse for the day's work, to catch the livestock for branding, and it was even spread in a large circle about his bedroll to keep snakes away when he camped on the trail. Whether or not the horsehair lariat really tickled the bellies of the snakes to such an extent that they would not crawl over it was not questioned too much; after all, it was easy to do and there was no use taking chances.

THE CHAMELEON

The American frontier cowboy probably picked up this lariat idea from the Indians, and perhaps the Indians picked it up from others, but the principle of lassoing was

used by the chameleon in Africa long before Indians ever fashioned a lariat from rawhide thongs. Nor did the chameleon have to construct its lariat: it was born with a tongue half again as long as its body with which it can do things no expert calf-roper could begin to do. The chameleon also lays claim to other firsts in nature, such as camouflage and an eye which is the forerunner of the ball-turret.

THE CHAMELEON TONGUE

A chameleon's tongue is something like a lariat shot from a cannon. A chameleon seven inches long can capture an insect a foot from its nose by ejecting this most amazing organ and hitting the insect with its sticky, bulbous end. This tongue, which normally lies contracted in the mouth, is very thin when extended, and thickens as it is retracted. However, the slowness of the unaided human eye makes it impossible for us fully to appreciate this most accurate and versatile insect trap.

How does the chameleon hurl its tongue such phenomenal distances and where does the chameleon store a tongue half again as long as its body? Actually, the tongue is forcibly shot from the mouth and the motive power is supplied by a slippery, slender, tapered bone called the "hyoid spike." The shooting of the tongue occurs something like this: first, the chameleon opens its mouth and the whole tongue base moves forward like a gun on a carriage, and careful aim is taken. As the chameleon fires, the ring muscle contracts suddenly on the slippery hyoid spike, this action shooting the tongue forward with great force. The insect struck by the bulbous end adheres to it and is drawn leisurely into the mouth of the chameleon by means of the now flaccid tongue. The sticky substance on the end of the tongue is renewed just prior to shooting

Adult chameleon in the act of shooting tongue toward insect prey.
(a) The tongue is just leaving the mouth.

(b) The chameleon's tongue caught fully extended in the act of snaring an insect.

(c) Chameleon withdrawing its long tongue with moth securely stuck to the end. Note that the outer portion of the tongue is quite flaccid during the return trip.

by pressing the end against the roof of the mouth where the secretion of certain glands maintains a coating.

It is little wonder that Africans seeing insects disappear into thin air before the chameleon thought that the chameleon spat poison.

COLOR CHANGE

The ability of the chameleon to change its color is well known. In this regard the true chameleon is often mistaken for the tiny little anoles, usually called "chameleons," which are sold at carnivals and fairs. Although these anoles are not chameleons, they do have this ability to change their color. The anoles are found only in the Western hemi-

Picture of a chameleon that is feeling mighty low during molting time.

sphere, principally in the West Indies and in Central America while chameleons are found in Africa.

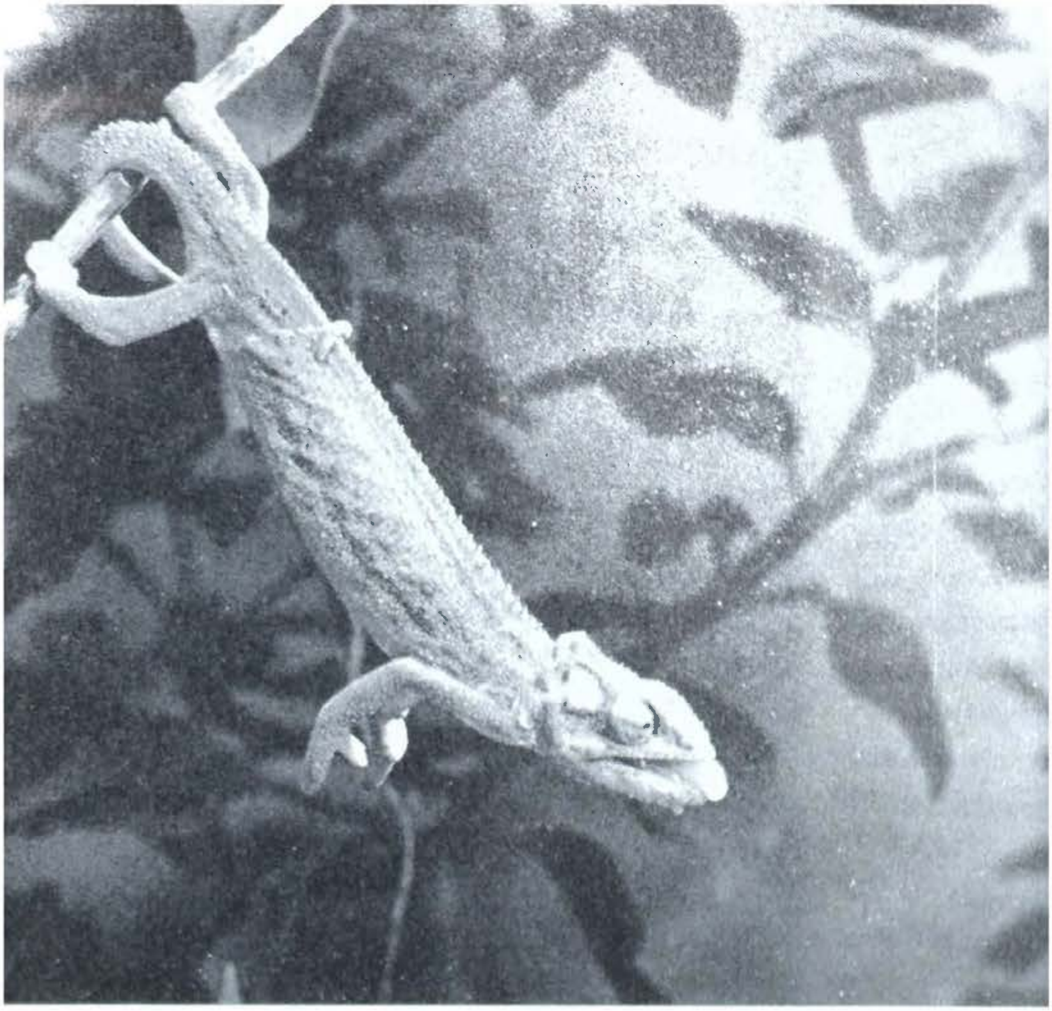
The outer skin of the chameleon is thin and colorless. This skin is shed periodically, making the unfortunate animal look (and probably feel) very strange with odd patches of dead cuticle clinging to it in the most unlikely places. Beneath this transparent cuticle are other layers containing cells which impart the color to the skin. First there is a yellow layer, the color being due to cells containing oil drops. By the action of the iridescent cells and the diffraction of light through the layers, light areas may be changed to green. Beneath the yellow layer is a white

one, and beneath this are the chromatophores or cells containing pigment. Very fine branches extend from these pigment-bearing cells out through the white and yellow cells. Upon the proper stimulus, pigment particles move toward the surface. When the branches contract, the pigment cells are forced back into the interior. Thus red, brown, or other colors may be imparted to the surface by the movement of these particles emanating from the chromatophores. When the particles are forced back into the chromatophores, the chameleon appears pallid. If, under extreme excitation, all the particles are forced to the surface, the animals will appear very dark or even black. While the comparison will not hold if carried far, this process of color change in the chameleon is similar to the human blush caused by the rush of blood to the surface of the skin.

It should be emphasized that the color changes are not necessarily due to the background upon which the chameleon is placed. It appears to be true that the color changes respond to emotional stimuli, like the blush. At least it is certain that when annoyed chameleons usually turn a dark brown or black. The intensity of illumination, the state of health, the temperature, etc., are all factors which have some influence upon the color change. In the Moody Institute of Science laboratories, one of the chameleons received from Africa became quite ill. During this period its usually docile nature was changed to one of extreme ferocity and sensitivity and its color became a deep black.

THE CHAMELEON EYE

Each eye is built like a ball-turret on a B-29 bomber. It protrudes in practically full hemispherical form from the side of the head and, what is even more startling, each eye can be controlled separately. A common use of this



Chameleon making ready to fling its long tongue at the prey. The prehensile tail in this case is looped over the limb and the end "clinched" over its back for a firmer grip.

strange ability is in the stalking of prey. While one eye is fixed on the insect, the other looks about for enemies or for likely limbs which can be used for support as the chameleon closes in. In gingerly selecting a place for placing its foot, the chameleon sometimes shifts eye duty so that the insect eye becomes the limb eye, and vice versa. Just prior to the catch, however, both eyes are concentrated on the insect and the job at hand of catching it.

Actually the eye protrusion is somewhat more cone-shaped than spherical with the small eye located at the apex. The extreme mobility of the eye compensates for the lack of ability to turn the head.

Comparing the chameleon's tail to the tail of the average garden lizard on anything like equal terms is a frightful affront to the self-respecting chameleon. The lizard has the rather distressing habit of shedding its tail when the little boy tries to impede its retreat by grasping it by the tail. The chameleon can no more shed its tail than a quarterback can shed a leg while being tackled. The chameleon's tail is far too useful an extremity to leave behind wriggling in the trail to serve as a decoy, nor if he did lose it could he grow another to take its place. The chameleon's tail is a vital, prehensile organ that serves him well in climbing. On a windy day it is wrapped around a branch for safety and when not needed it is coiled neatly like a hawser on the deck of a naval vessel. In fact, one chameleon that expired in the Moody Institute of Science laboratories was found black and cold, hanging by its tail from a limb!

At no time is the chameleon's tail more depended upon than while shooting its long tongue at an insect at a greater distance than can be spanned by the tongue alone. To span this too great distance, the chameleon uses its lithe body. The two hind feet and the tail form a three-point suspension which is so strong that the chameleon's body can be stretched horizontally with no support other than this. Sometimes the tail is simply wrapped around the limb. At other times the tail is passed around the limb, up past the side of the body, and the end of the tail is clamped across the back much as a nail is clinched after it has passed through a board. (See photograph p. 74.)

All of the approximately 80 species of chameleons have such prehensile tails except the dwarf forest chameleon *(Brookesia)*.

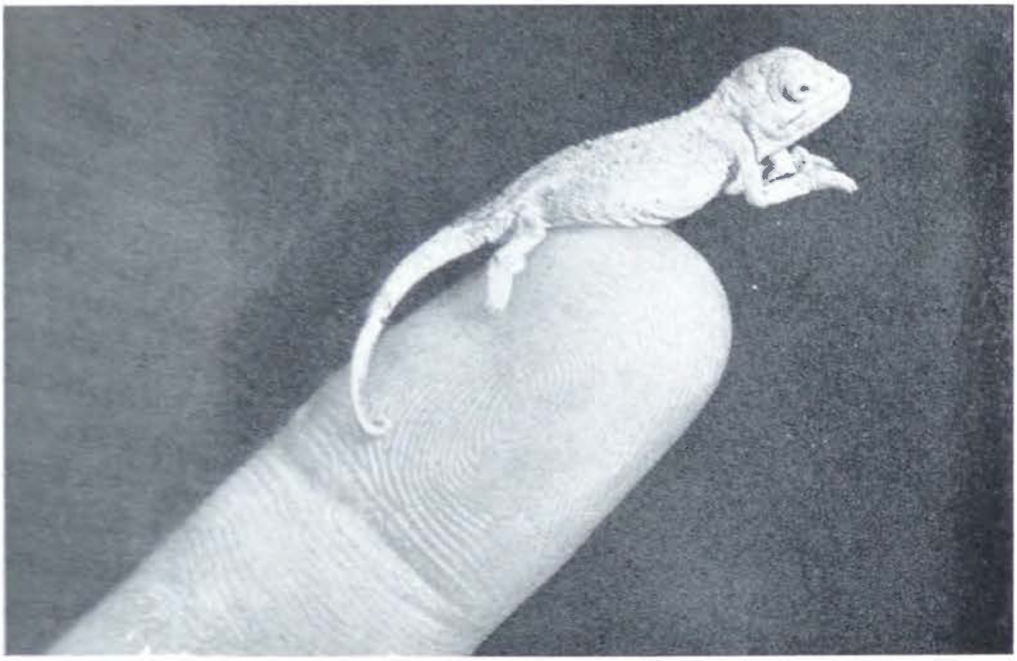
CHAMELEON FEET

The feet of the chameleon will immediately be noticed as something different. These are not the running feet of the lizard, these are extremities peculiarly fitted for the tree-climbing activities so close to the heart of the chameleon. The "fingers" are almost fused together, two on one side of the limb and three on the other. These groups of toes are at right angles to the body which is singularly proper when one considers that the limb on which the chameleon crawls is parallel to its body. On the two forefeet, the five fingers are divided in such a way that two are on the outside of the branch, and three inside. This gives the animal a greater clinging ability but, if these four very special feet are not enough on a windy day, the tail is wrapped around the branch for an additional factor of safety.

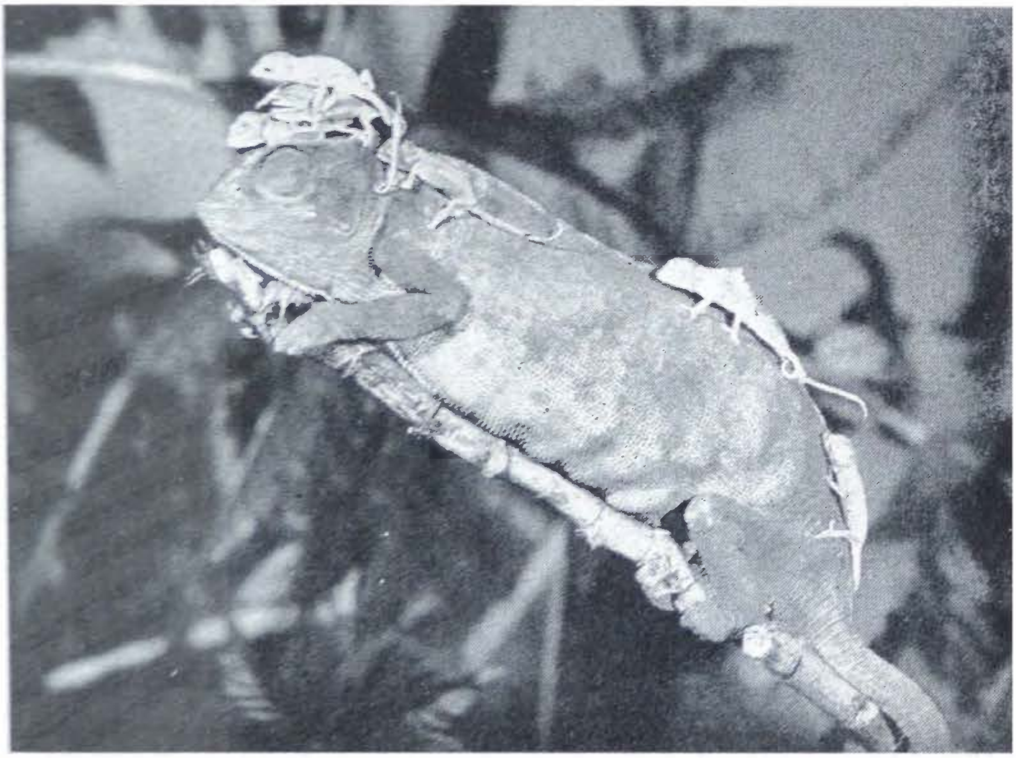
Loveridge tells of an unusual incident which bears out the remarkable nature of the chameleon feet. He released one on a second story balcony, thinking that there was no way for it to escape. The resourceful animal promptly departed on the telephone wire. It traveled 90 feet on this wire which was 20 feet above the ground, and climbed down a very slender iron pole to the ground below.

CHAMELEON YOUNG

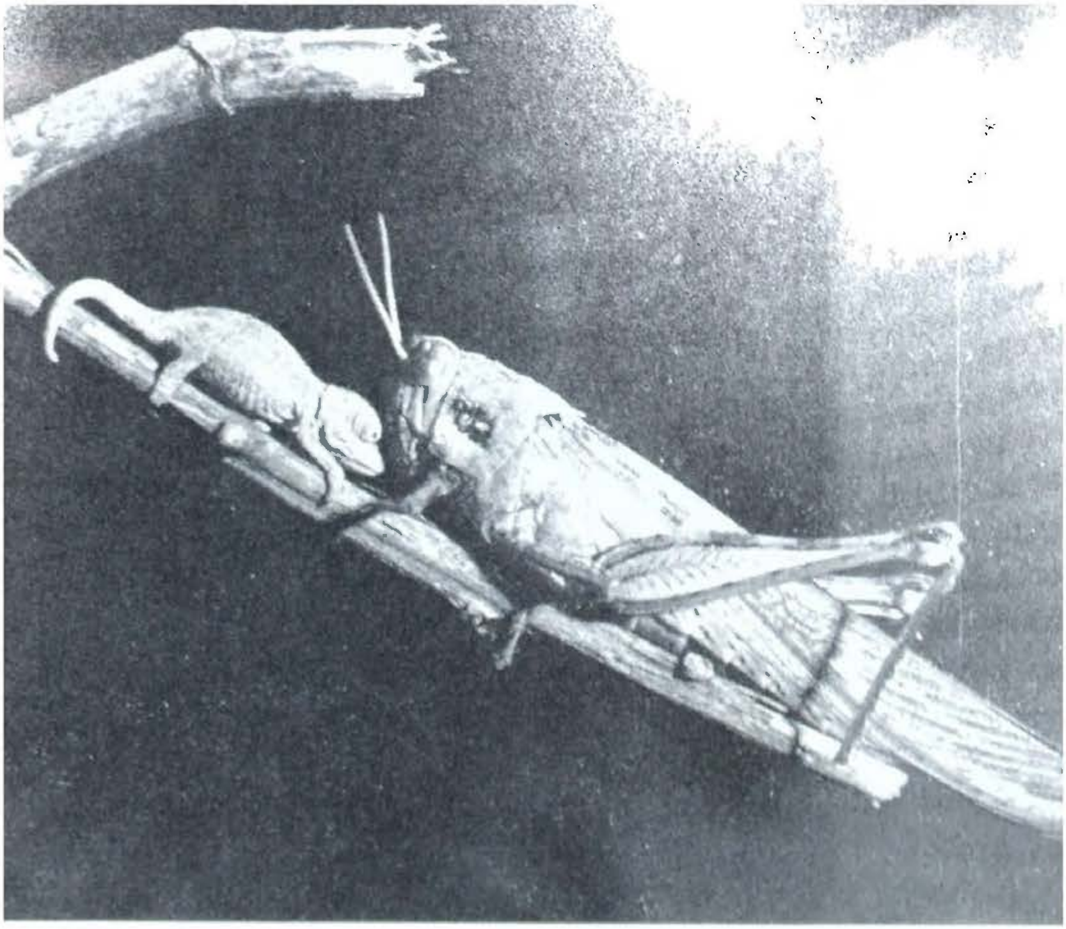
It is very hard for herpetologists to tell a male chameleon from a female, but it does not seem to be difficult for chameleons. Seemingly well-established convictions on the sex of a chameleon may be dashed to pieces as "he" presents to the world a couple dozen tiny watch-charm-sized babies. The babies of some species are hatched from eggs that are buried in the sand. The eggs of other species are incubated within the mother and deposited on the limb.



From the day of birth the precocious baby chameleons forage for their own food and water, and climb all over the shrubs.



Baby chameleons a few days old swarming all over an oldster trying to catch forty winks.



Adult chameleons like to eat nothing better than grasshoppers, but here an outsized grasshopper and a diminutive baby chameleon but a few days old make the reverse appear quite possible.

In the struggle to escape from their membrane, the babies frequently fall off the limb which seems to bother them not one bit for they immediately climb back up the shrub. Sometimes the membranes break within the mother, allowing the baby to make its debut in a manner that, to a casual observer, appears to be quite mammalian in character.

The baby chameleons are very precocious, being able to climb, use their prehensile tails, and catch flies with their tongues almost from the very time of birth. These babies are very small replicas of the adult chameleon except that their eyes are relatively larger, giving them a comical "bug-eyed" appearance. The scaled down appearance of

the babies is further enhanced by their actions as they set out to mimic mother in every action from the curling of their tails to the use of their tongues.

At the Moody Institute of Science a shipment of chameleons was received from a missionary friend in Africa. These were used extensively in photographic activities, including high-speed electronic flash photographs of the tongue in action. One morning we were surprised to see one of the chameleons dead on the floor of the cage in which they were kept. As it was being examined, a chance glance to one side of the carcass revealed a tiny baby chameleon, about three-quarters of an inch in length. The echoes of exclamation had hardly died away before another was sighted, and another, and yet another. All told, thirteen babies were found.

As one learns more about the remarkable nature of the tongue of the chameleon, one is filled with admiration at the unusual design, the structural soundness and its operational efficiency. Probably we have all shot slippery watermelon seeds from between our fingertips and have been surprised at the remarkable force that can be imparted to the seeds in this way. Actually, the same principle is used to eject the tongue of the chameleon as the ring muscles of the tongue clamp down on the slippery, tapered hyoid bone. The lariat, while similar in function, cannot boast of such an ejecting mechanism nor such accuracy, and we see that again nature was first — that God has walked this way before, generously strewing organisms which utilize physical principles and arrangements that foreshadow the inventions of man.

REWARD!

WANTED ALIVE!

THE BOLAS SPIDER

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Phone AR 9-3983 or BR 2-1286 during the day

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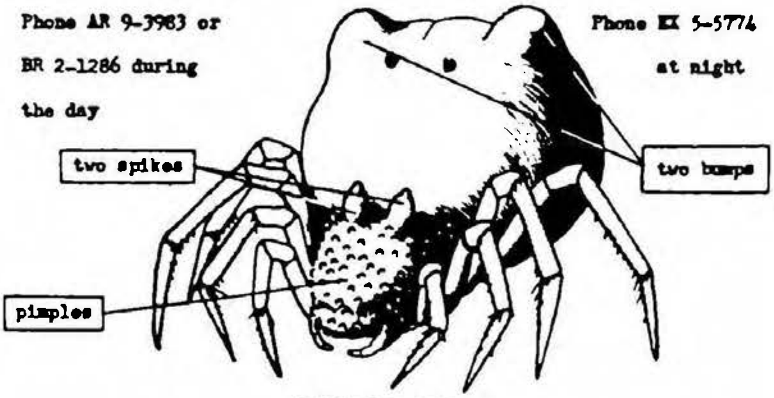

HOW TO RECOGNIZE

1. Spider is plump, usually about ½ to 1 inch across the body.
2. Two spikes just in front of the fat abdomen.
3. Usually sitting quietly on twigs near its egg sacs, which hang from the twigs on silken strands.
4. Both egg sacs and spider are a mottled brown and white color, resembling bird droppings. Because of this the spider is often called the "Bird Dropping Spider."

WHERE FOUND

1. In both countryside and city.
2. Usually not higher than six feet from the ground.
3. On fences and shrubbery.
4. On trees, particularly cedar, cypress, and conifers.

MOODY INSTITUTE OF SCIENCE
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Poster sent out to high schools in the Los Angeles area to encourage students to help the Moody Institute of Science photographers find bolas spider specimens.

Chapter 5

THE SPIDER THAT THROWS A BOLAS

THE BULLETIN BOARD outside the door of the biology classroom of Lincoln High School bore a new and gaudy announcement. "WANTED . . . . REWARD!" Pressing closer and peering around several bobbing towheads, one could see what was wanted—a spider! The Moody Institute of Science was willing to pay for live specimens of the ugly spider pictured. Ten dollars for the first two to be brought in, five dollars for subsequet ones until the need was met! Why not work this into the biology field trip? All in the interests of science! Such was the rather unusual way we managed to gather enough bolas spider specimens to complete our photographic project of capturing the amazing exploits of this trapeze artist on color motion picture film. A high price for a spider? It would be difficult to keep from starving by catching these spiders at a thousand times this amount for this spider is very hard to find.

The bolas spider *(Mastophora cornigera)* has nothing in its appearance that would make one suspect anything unusual in its method of trapping its prey. It is a fat spider, less than one-half inch across its body. It is adorned with all sorts of projections, lumps, and wrinkles and the coloring is very drab. It is predominantly brown in color,

The bolas spider sitting among the tangled webs of old trapeze lines which are reminiscent of former nights of hunting with her sticky bolas.

splashed with white which gives it one of its common names — the "bird-dropping spider."

In the human family, great exploits are likely to be associated with bravado and swagger, but not so with the bolas spider. It is one of the most retiring spiders imaginable and one of the most difficult to find. Its habit of not spinning extended webs also contributes to the difficulty of finding it. The best time of the year to look for these spiders is in the Fall, for this is the time one is most likely to spot the suspended, spherical egg sacs and thus have evidence of their presence. Without such a telltale marker it is very difficult to spot these spiders for they are immobile during the daytime, frequently secreting themselves out of sight on fences, limbs of trees, or shrubs. A common place to find them is the outer extremes of branches of trees or shrubs several feet above the ground. Sometimes shreds of former web lines draped carelessly over a limb indicate the presence of the bolas spider.

MAKING THE BOLAS

This spider would be passed off as just another of the many spiders in the garden if it were not for its unusual use of the products of its spinnerets in catching its prey. It is really an orb weaver that has gone wrong with a vengeance, the scientific specialist would tell us. Whether this action is a built-in instinct from the beginning or whether it is an acquired habit, we can but guess. After the sun has set, the very immobile spider begins to show signs of life. First she presses her spinnerets against the underside of the selected twig and pulls out a silvery thread as she crawls along the underside of the twig. After crawling along six or eight inches, carefully keeping the thread from becoming entangled with the rough surface

of the twig, she secures the other end. This thread sags considerably and the sag plays an important part in giving her enough room to carry on the next phase of the drama. Sometimes this slack line is reinforced with another strand, or it may be used in single strength. Her fat body hanging from this thread by the very tips of her legs, she moves with agility to the center where she presses her spinnerets to the trapeze line and draws out another thread which is kept clear of the trapeze line with great care. When a length of about two inches is drawn out, the spider begins a curious procedure of combing out additional silk material from the spinnerets into a glistening ball on the taut short thread. By alternate strokes of her hind legs, the spider accumulates within a few minutes enough of the shining silk to make a ball about 3/32 inch in diameter. At this stage, considering the viscid glue ball finished, she spins more thread in order to lower the glue ball to a vertical hanging position without swinging wildly and becoming tangled. This temporary line is then cut off just below the ball; the spider, hanging from the trapeze line by the legs on one side, reaches out and carefully takes the glue-ball suspension line in the claw of one front leg, the ball being about an inch below the claw.

USING THE BOLAS

She is now ready for action. The approach of a moth is fully sensed by the spider as she makes many small adjustments of her grip on the line. When the moth is within range, the spider hurls the glue-ball toward it, striking it on the body or wing and securely tethering the wildly fluttering moth on the end of the delicate but strong tether. Like a nylon rope, this tether will stretch half its length before it breaks, all the while the spider is holding on for

dear life as the moth desperately tries to escape. The sticky ball holds the struggling moth in spite of its gyrations. As soon as she is sure of her catch, the spider slips down the tether and paralyzes the moth with venomous bites while the two of them rotate crazily on the end of the thread.

METHOD OF ATTRACTION

It is not known just what attracts the moth to its doom on the end of a silken bit of thread. Surely there must be some attractive force, or the chances of a moth passing within striking range of the bolas spider would be very small. It might be a scent, but the human nose detects no unusual odor around the spider or its glue-ball. Some authorities have suggested that the feeble light of the evening caught in the clear surfaces of the glue-ball attracts the moth, but it strains the credulity to believe this even in view of their night-adapted eyes. Whatever the means, the result seems assured for the moths are apparently attracted to the spider by some means or other.

THE BOLAS ABROAD

The bolas spider, so widespread over the United States, has foreign cousins that vie in unusual means of trapping their prey. The Australian spider of this group has been studied much more thoroughly than our domestic one and has been observed to act in roughly the same manner in spinning the trapeze, forming the globule of viscid material, and in swinging it at the moth. In Africa, however, *Cladomelea* adds a new and novel twist to the bolas routine. Instead of grasping the bolas line by the long front leg, *Cladomelea* uses the short third leg and clings firmly to the trapeze lines by the others. With this short leg it whirls the bolas in a circle continuously for fifteen minutes

or so in a horizontal plane. If nothing is caught in this time, the bolas is drawn up, eaten, and another fresh one is made and the performance is repeated. From time to time a passing insect is caught on the whirling glue-ball, meeting the usual fate of being sucked dry by the spider.

LIFE HISTORY

The female spider lays her eggs and encases them in a skillfully contrived egg sac of approximately the same size as the spider. This sac is supported on a characteristic long stem, usually in the vicinity of the favorite bolas throwing haunts. The female usually dies in the fall and does not live to see the babies emerge from the sac in the spring. Each female makes about five egg sacs, each containing approximately 150 eggs. Thus more than 700 spiderlings might result from the procreation activities of a single female. Only a very few of these reach maturity.

An interesting feature of the bolas spider is that among the tiny babies emerging from the cocoon are some that are somewhat redder than the others. Microscopic examination of these will disclose that they are the males, armed with fully developed bulbous enlargements near the ends of the front legs which are male organs. It is not known for certain whether these precocious males mate with last season's females ten times as large as they are, or whether they wait some six months until baby sisters mature.

THE BOLAS OF THE PAMPAS

The bolas spider takes her name from the bolas of the gaucho of the Argentine. This cowboy of the Pampas uses the bolas (or boleadoras) to catch cattle and ostriches. Some times called the "three Marias," this is a very tricky device of weights and rope. Three leather ropes about six feet long radiate from a common point and bear a stone weight

on the end of each. The gaucho holds one of the weights, whirls the bolas overhead, and lets fly at the target. The weighted ends of the ropes wrap the rope around the ostrich's neck or legs and throws it with a resounding thump. The shrill cries and the pounding hoofs are still there, but the throwing of the bolas has largely disappeared from the Pampas because it is too easy to break the legs of cattle by stopping them with such suddenness. However, the bolas is still carried in a pouch on the saddle as a reminder of hard-riding yesterdays.

Yes, the bolas spider was named after this device of the hard-riding gaucho of the Pampas, but this does not mean the gaucho was first. The retiring spider with the skillful application of the silk from her spinnerets in catching prey takes the honors of the prior claim. No pounding hoofs or shrill cries herald her masterful bolas construction as she repeatedly constructs these sticky lassos through the evening. Sometimes the hand of God appears dramatically in the storm, or with fearful violence in the earthquake and the volcanic eruption, but for every such manifestation there are thousands upon thousands of footprints of God that are quietly hidden from the eye of man, such as the bolas spider. Perhaps these are reserved for the patient seeker; perhaps in God's providence they are revealed a little here, a little there, that there might be a continuous flow of evidence pointing to His power and might, His majesty, His everlasting glory.

The archer fish *(Toxotes jaculator)* dispatches a jet of water, dislodging an insect from a fern frond. This is the case of the flat trajectory which requires a great correction for refraction.

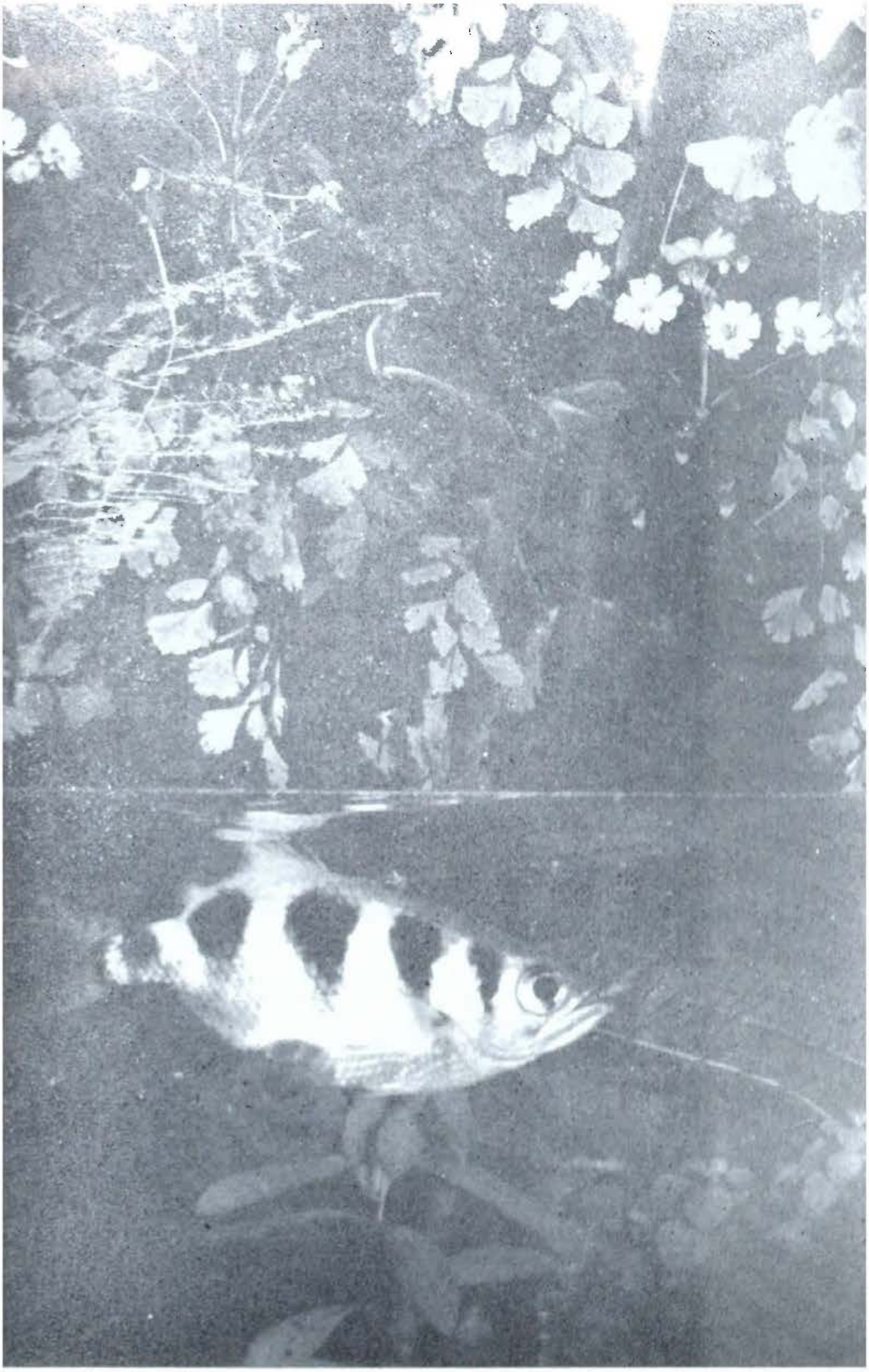
Chapter 6

THE FISH THAT SHOOTS

BECAUSE OF THE ABILITY of knocking insects down with a well-directed jet of water squirted from its mouth, the archer fish, *Toxotes jaculator,* is of tremendous interest not only to science but also to the man on the street. It isn't every fish that can claim the distinction of being able to spit "through the knothole in grandpa's wooden leg" at a distance of six feet! It is no accident that this fish is such a marksman either, for its mouth is equipped with some very special equipment without which it would lapse into a spitting inferiority with most of the rest of us.

Toxotes is a native of the brackish and coastal waters near the mouths of rivers of southern and southeastern Asia and of the islands from India to Polynesia. Much of the scanty information available on these interesting fishes comes from observations in Thailand (Siam) and Batavia, although the East Indian countries, the Philippines, Malaya, and Burma can also lay claim to the envious distinction of having this fish as a native.

The archer fish is quite gregarious, choosing to live in small, loosely knit groups. It lives largely on insects that hover over the water surface or alight on the vegetation near the water in which the fish lives. Shrimps and insect larvae provide some food as well as insects which accidentally fall on the water surface; but observing the actions of this fish for a few hours leaves one with the firmly



Although this tidbit was obtained in a very unusual way, the archer fish gobbles it in a very ordinary way.

imbedded conviction that if Toxotes has its choice, it will take a sporting chance on knocking insects off overhanging limbs or even out of the air as they fly overhead! Of course, there is real trouble in scratching around the laboratory to find insects enough to satisfy the insatiable appetite of this fish. Zolotnisky had his troubles along this line at the turn of the century and finally hit upon the idea of placing a wetted blade of grass near an ant hill. The fish would then greedily shoot the ants off the blade of grass as it was held in the air above the fish. In the laboratory of the Moody Institute of Science we were finally driven in desperation to try meal worms. Everyone knows the propensity of most fish to show at least some interest in a worm on a hook in the water—but would the archer fish be willing to shoot them off the overhanging leaves with its jet of water? We tried it and were amazed to see the fish shoot as though their little hearts would burst as one after another the meal worms were knocked down to the water surface by the water jet and immediately devoured by the fish. In fact it was always a contest to see which fish reached the worm first, for the most worms go, not to the best marksman, but to the fastest fish in the scuffle.

The archer fish is shaped like an oval with the top front part of the oval flattened off. The mouth is deeply cut and is characterized by a protruding under jaw. The dorsal fin is also set far back, giving the fish something of the appearance of the ocean sunfish.

In Thailand the archer fish is called *Pla Sua,* or "tiger fish," because of the prominent markings on its sides. It is, generally speaking, a silvery color but superimposed are six transverse bands of black alternating with yellow bands. These colors vary considerably due to environmental influences. Almost every change in external conditions is

accompanied by a definite change in color. The amount of food, the lack of oxygen in the water, the general condition of health, fright, etc., are all reflected in color changes. Even the dark bands disappear under nocturnal conditions. The temperature of the water has a great effect: at 70° Fahrenheit, the colors are bright and clear but become quite dull for lower temperatures.

HISTORY AND MISCONCEPTIONS

There are few cases in history where the story of an animal has been so thoroughly misunderstood and disbelieved as that of the archer fish. In the early 1700's reports reached Europe of a strange fish in the east Indian countries that could hit insects by squirting water at them. While many fabulous reports from strange countries were being received during this period, this was just too much to believe. In 1764 and again in 1766 Governor Hommel of a hospital in Batavia sent descriptions of the archer fish to England. These papers were read before the Royal Society by John A. Schlosser, M.C., and a specimen sent by Hommel was presented to support his story.

During the nineteenth century there were few, if any, observations added to the meager fund of information on this fish. Most of the authorities during this period frankly did not believe that this fish could squirt water as described. For example, Dr. Peter Bleeker, the author of more than 400 scientific papers on fish of the orient — who lived in the very same city as Hommel — was unable to verify the performance of the fish and in 1875 declared firmly that the fish could not fire such a jet of water. In 1880 Dr. Francis Day, another outstanding authority on the fishes of India and Burma, could not verify the story in spite of his

quarter of a century in the same general part of the world studying the fishes.

Further research has resulted in a solution of the problem. Governor Hommel described the shooting activities of one species of fish, *Toxotes jaculator,* and sent another as specimen. The specimen he sent was *Toxotes chelmo,* a non-shooting fish, instead of the one he had described so graphically! If blame must be placed for this great error, which threw the study of this fish into a cocked hat for about a century and a half, at least part of it might be laid at the door of the Malay natives who called both *jaculator* and *chelmo* by the same name.

During the twentieth century real progress was made in the understanding of this much-abused fish which, not realizing that the best minds in science were stating that it could not shoot jets of water, went right on knocking off insect after insect, century after century. Finally, as befits such skill in marksmanship, he was recognized the world around not only as a properly described and recognized atom in the classificatory tomes of science, but also as a good sportsman, a good marksman, and a very entertaining individual! At the turn of the present century, Zolotnisky settled most of the questions by observing living specimens in Singapore. While the recorded observations of Zolotnisky have been generally confirmed in recent years, and, in fact, may be confirmed by anyone fortunate enough to obtain possession of one of these remarkable fishes, complete acceptance was not granted as late as 1909. The famous Dr. Theodore Gill in that year said of Zolotnisky's far-reaching observations and conclusions on the archer fish, "Certain assumptions respecting the power and range of vision among fishes, as well as the intelligence and reasoning powers of such lowly animals [are exaggerated]."

The archer fish, native of East Indian and Malayan streams, demonstrates his skill in knocking insects from overhanging plants by a stinging jet of water. This is the case of the near vertical trajectory for which refraction effects are minimum.

THE SHOOTING MECHANISM

In spite of all the talk about the shooting ability of the archer fish over several centuries, the shooting mechanism itself was not described until 1936. Hugh M. Smith, Fisheries Advisor of the Kingdom of Siam, had ample opportunity to watch these fish critically. By holding a fish in his hands in a bucket of water and squeezing the gill covers he could eject a jet of water from its mouth distances as great as three feet. Marveling how scientists through the years had missed such obvious organs, he described the mechanism. In the roof of the mouth is a long narrow groove which is converted into a tube of small bore by the tongue. In a seven-inch fish, the bore of this tube is about 1/16 of an inch. The tongue pressed closely against the roof of the mouth forms the tube, and as the gill covers are compressed, water is ejected. The tip of the tongue acts as a valve, regulating the flow. The pharyngeal cavity serves as the compression chamber and a reservoir for water of sufficient capacity that a series of jets may be ejected in rapid succession.

Is the water ejected in the form of a series of drops or a continuous jet? The early authorities seem almost always to refer to the fish's practice of "shooting drops of water" (Smith) or "shoot . . . the single drop" (Hommel-Schlosser), or "shoot a drop of water or perhaps drop after drop at the fly" (Gill). Zolotnisky pictured the archer fish as shooting individual drops of water and this common impression has been perpetuated by many modern artists. At the Moody Institute of Science still photographs were made with an electronic flash source having an exposure duration of about 1/10,000 of a second. The human reflexes were at first depended upon to trigger the exposures, but it was found that the reaction time was entirely too long to catch

the jet. A delicate switch was devised that utilized the weight of the water in the jet to operate the flash. It was arranged so that as the jet reached the branch on which the meal worm rested the circuit was completed firing the flash light source. More than a dozen such pictures were taken, each one catching the water jet as a continuous stream from the mouth of the fish to the target! It must be emphasized that enlarged frames from motion pictures of the shooting of the jet would not offer conclusive evidence on this problem because the exposure time would be in the order of 1/50 second for standard speed. This would allow the individual droplets (if such existed) to merge into an apparent jet because of the motion of the water. A photograph has been widely published showing five well-defined droplets between the mouth of the fish and the target. A study of these pictures obtained by short-duration flashes makes one suspect that the drops have been drawn in by hand in this photograph or else the fish used behaved entirely different from the ones observed at the Moody Institute of Science.

VISION

One cannot study the archer fish long without being impressed by its eyes. Without attributing to the fish the extreme expressiveness and intelligent sparkle which Zolotnisky emphasized, the keenness of vision is obvious. This fish can spot and knock down small insects at relatively great distances and it is quite certain that considerable discrimination and selection of insects goes on. The distance to the target is accurately gauged and the force of the jet stream is thus controlled. If the insect is not dislodged on the first volley, a rapid series of jets does the trick. All this would indicate extremely sharp eyesight. The bright eyes

have great mobility being able to turn forward, upward, backward, but not downward.

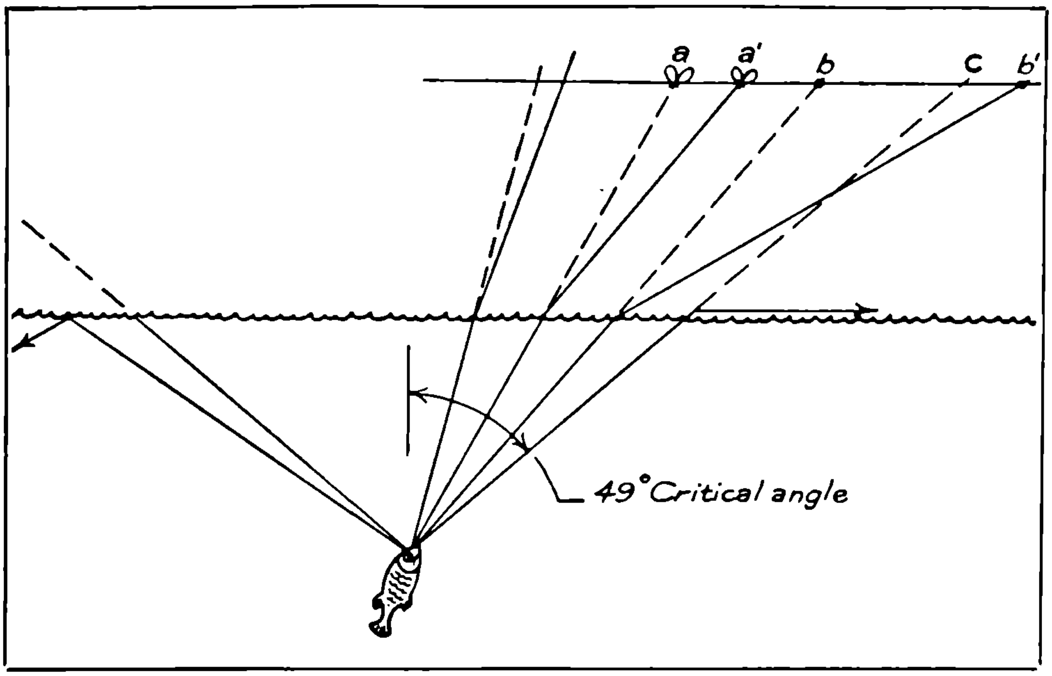
MARKSMANSHIP

In native streams the archer fish usually lives in muddy water and thus is forced to swim very near the surface, leaving a characteristic wake which the experienced can spot at once. In the aquarium, however, the fish characteristically seeks the protection of aquatic plants until an insect is placed on an overhanging plant. The fish swims to position in a very positive way, pointing toward the prey. It may swim backwards a bit as it maneuvers itself into proper position for shooting. As the tip of the mouth touches the surface, the water jet is shot without hesitation. The distance normally covered is from 12 to 20 inches, but 40 inches is not uncommon. In the Moody Institute of Science laboratory, spent jets of water have hit photographic lights at distances of more than 40 inches, the cold water causing the hot bulbs to shatter!

Baby archer fish 2 or 3 inches long are reported to emulate their parents to the best of their juvenile ability by ejecting feeble jets of water.

Smith reports the experiences of a friend in Siam who entertained guests by the antics of archer fish. By dangling a spider on a black thread from his veranda which hung over the water, the archer fish could be induced to display their marksmanship. Such shooting left water marks on the ceiling of the veranda some ten to twelve feet above the water surface.

The literature seems to indicate that flying insects form only a small portion of the diet of the archer fish, and our observations under laboratory conditions offer no further



In addition to all of the usual problems all shooters must solve, the archer fish must correct for the effects of refraction, or the bending of the light rays as they pass from air to water. The amount of this bending varies with the angle. Beyond the critical angle of 49°, there is total reflection and the fish can see nothing above.

information on this interesting point. However, it is of great interest to consider the difficulties encountered by this fish when it does shoot an insect from the air.

TRAJECTORY OF WATER JET

When we come to considering the jet of water expelled by the fish, straight lines no longer apply because of the finite weight of the water in the liquid projectile. Gravity acts on the water, giving it a trajectory in the form of a parabola (neglecting air friction). This curve is of the same shape as that followed by a rifle bullet, a baseball (neglecting the "English" a pitcher might put on it), or any other projectile having weight. In the baseball it takes a lot of practice to overcome this downward pull of gravity sufficiently to throw the ball accurately. In the rifle the sights are adjusted to compensate for the normal drop of the

bullet. The centerline of the rifle barrel must be raised above the target to allow proper compensation for the fall of the bullet due to the influence of gravity.

The archer fish must also compensate for the effect of gravity on its water jet. How it does this, we do not know. If the fish were always to shoot vertically, it could minimize the effect of gravity on its aim, but actually it shoots at any convenient and appropriate angle, making the varying amount of correction needed without a flick of its fishy eyebrow. It should be emphasized that corrections for the effect of gravity change with the vertical angle of shooting. Thus there is no fixed correction that will always care for gravity effects, but a different solution for every situation.

CORRECTION FOR TARGET TRAVEL

So far we have considered an insect that, with great consideration, flutters gracefully in one spot like a hovering hummingbird or sits dutifully on a twig. While this sometimes happens, our friend the archer fish would no doubt consider itself quite limited if it could operate with accuracy only in such instances. Obviously, the archer fish must "lead" its moving target by just the right amount in just the right direction to hit the insect rather than a spot where the insect has recently been. The antiaircraft gunner must shoot ahead of his target, and the speed of the projectile, the speed, direction and elevation of the target are all factors that must be considered in order to solve this problem fully. The archer fish must do this also.

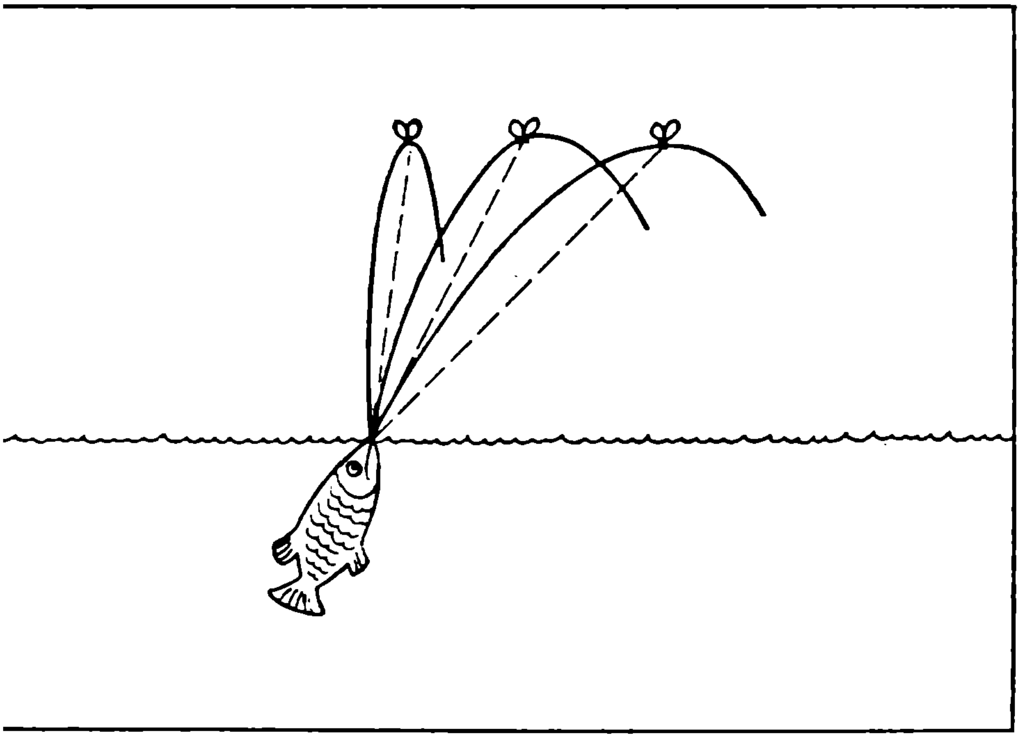
We must not be confused by the apparent ease with which the archer fish solves these difficult trajectory problems. Since creation man has been busily engaged in the art of waging war upon his fellow man, and most of his

energies have gone into the solution of trajectory problems. Throwing stones, hurling spears, or shooting arrows requires skill and attention to these problems, consciously or unconsciously. With the advent of gunpowder even greater efforts were concentrated upon devices for making rapid trajectory calculations. With the antiaircraft gun this is a very complex computing machine. The most modern radar-directed gun is controlled by a maze of electronic circuits which have only recently become possible, a sort of capstone of the electronic age, a crowning achievement of modern applied science, one of the most clever instruments yet devised by man. But nature had it first again. This unassuming little archer fish has been solving all of these complex trajectory problems in his tiny calculating machine long before man arrived on the scene. But this isn't all.

REFRACTION EFFECTS

Have you ever tried to shoot fish? It is the most exasperating experience, for the fish is not where it appears to be. Light travels about 33% faster in air than in water, causing the light rays to bend. The archer fish in the water looking at an insect flying in air has this refraction problem to solve. What is more, this effect is present no matter at what depth the fish places its eye. As the insect flies past the fish at a constant height above the water, the refraction error introduced is continually changing to the fish lying in wait. For example (see figure page 98), when the insect is directly overhead, the fish sees it exactly where it is. When the insect is actually at *a,* to the fish's eye it appears to be at *a′*, and when the insect is actually at *b,* it appears to be at *b′*.

There is one other effect due to refraction that works to



The archer fish must solve all of the problems of the anti-aircraft gunner: and more so. This illustrates the effect of gravity on the water jet making it necessary for the archer fish to shoot above the target. This parabola is the same curve followed by a baseball, or rifle bullet.

the advantage of the insect and to the disadvantage of the fish. As the insect flies past position *c*, he disappears from the view of the fish. This angle is called the "critical angle" and the ray is bent entirely down to the water surface. For angles greater than this critical angle the underside of the water surface acts like a mirror and actually appears so to a diver or a fish beneath the water. This means that all that is seen by the fish must of necessity be that light coming through a "window" cone formed by rotating this 49° ray.

Does the archer fish select the vertical shot because of its easier nature and avoidance of refraction and trajectory problems? A study of the photographs appended will demonstrate that it does not necessarily limit itself in this way. Some of the photographs show shots close to the

vertical, probably because the area beneath the target is cleared of aquatic plants. Other photographs show inclined shots, and it will be noticed that the area under the target is, in this case, choked with plants. All of the shots photographed are bull's-eyes.

* * * * * *

Thus the archer fish solves the same problem as the antiaircraft gun crew: this involves the parabolic trajectory and the position and motion of the target. In addition to this feat, remarkable in itself, the archer fish must also compensate for the effects of refraction as its eyes are in water and the target in air. All of these factors, trajectory, position and motion of the insect, and refraction must all be treated together, the solution obtained, and all corrections "cranked in" in the brief interval our prize sharpshooter sizes up his quarry!

To me this is one of the most amazing things in all nature. This archer fish has anticipated and solved all of the shooting problems met by man and has gone one better by tossing in the utterly complicated light-bending problem as well. And does it take a flat-car full of equipment to do it? Not for the archer fish. It would be unreasonable to attribute such obviously great intelligence to the archer fish itself. This is just another shadow of the supreme intelligence of God which an alert eye and an open mind can see in all of the creatures around us. An understanding of this most difficult problem which the archer fish habitually solves serves only to magnify the name of Him without whom was not anything made that was made.

Chapter 7

THE BIOLOGICAL BENTHOOSCPE

OTIS BARTON cast an apprehensive eye over his instruments. A bewildering din told him the bolts were being tightened on the heavy steel door of the Benthoscope. This was the big moment! This was the try for a new world's record! Barton's thoughts raced back nineteen years as he recalled the same feeling in the pit of his stomach as he and Dr. William Beebe were bolted into the smaller, thinner Bathysphere. That first dive took them down 1400 feet — how far would he go today? And then two years later he and Dr. Beebe went down 3028 feet. That was a good dive. Everything has to go just right to lower a man in a sphere that far and bring him up again before the oxygen supply gives out. Now a dive a mile....

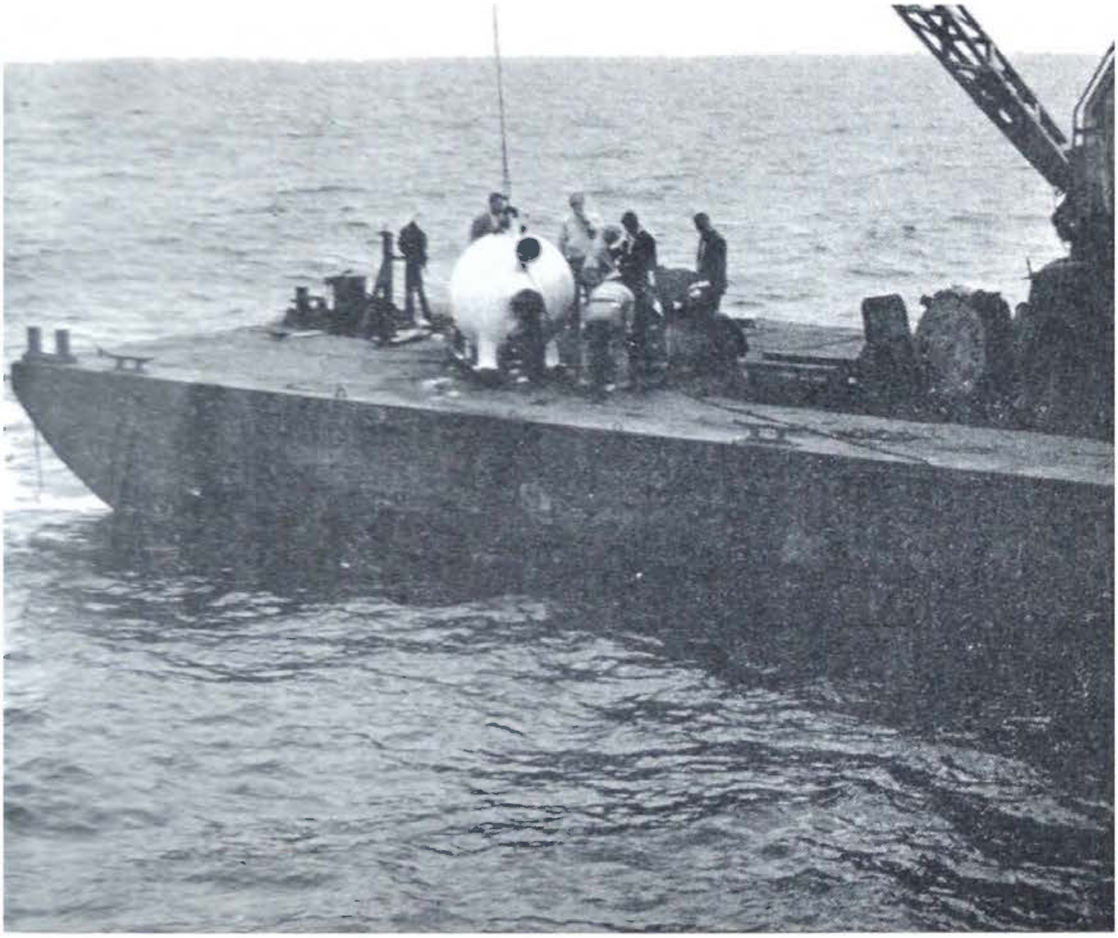
"Are you ready?" It was Dr. Nelles on the telephone as he peered through the quartz port at the shadowy figure of Barton within. Barton suddenly realized the clanging had stopped as he touched every precious instrument with his hand as he silently called the roll: the oxygen bottles, the aneroid barometer, the screen trays of soda lime, the electric fan, the old-fashioned palmetto fan to circulate air if the electricity failed, the flashlight. Yes, the blanket — it will be close to freezing down there.

"All ready," Barton called, and the derrick lifted the

Dr. Maurice Nelles, research engineer, stands by as Otis Barton climbs gingerly over the rough edges of the Benthoscope door.

heavy Benthoscope neatly off the deck and lowered it into the water surface opposite the winch. The green water rhythmically slushed over the port as the sphere dangled, yielding brief glimpses of the barge and the Velero IV mother ship to Barton within. When the sphere was transferred from the derrick line to the long special descending cable, the signal was given to Barton and he said he was ready for the descent.

There was a sudden lunge of the sphere and the interior was flooded with eerie green light as both ports splashed below water. Everything became still except Dr. Nelles' steady flow of chitchat which was continually requiring

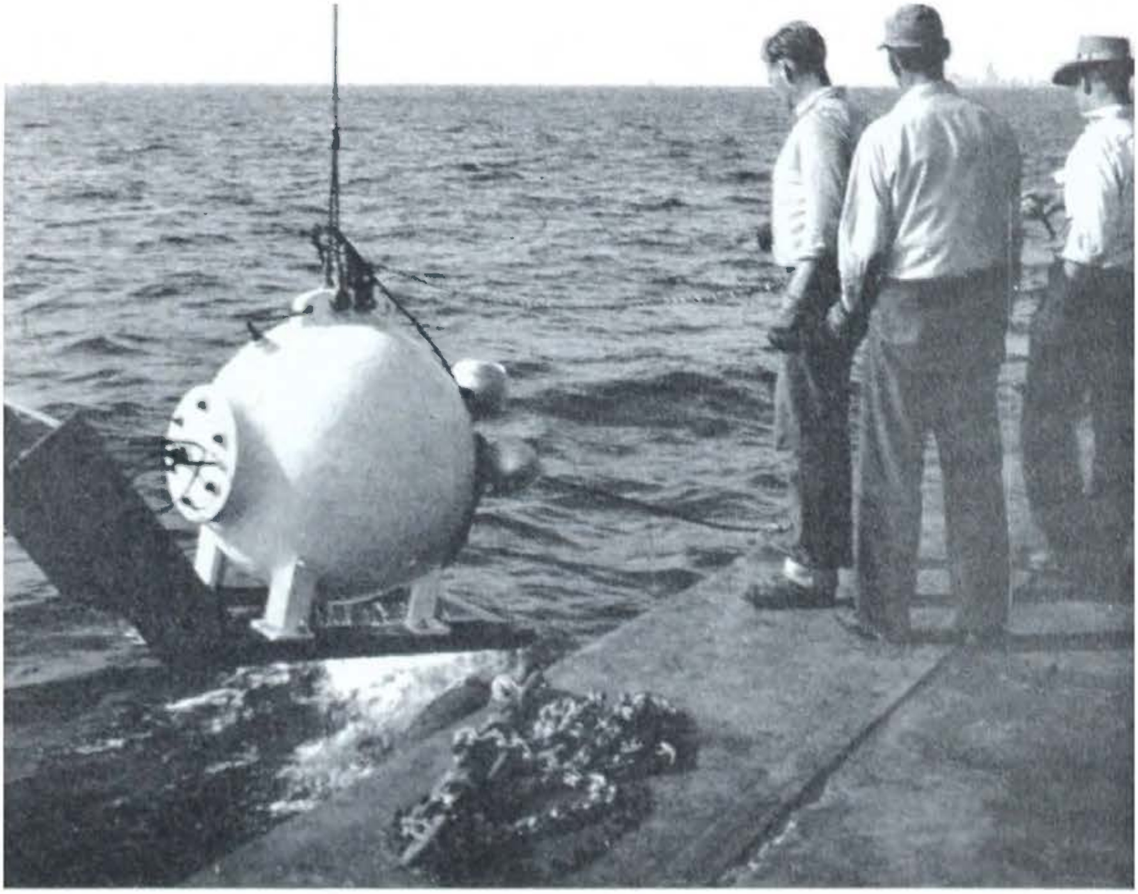


The Benthoscope being readied for the world's record dive to a depth of 4500 feet off Southern California.

answers to check Barton's well-being. A snapping and crunching sound made by the turns of cable on the winch was transmitted down the cable like a child's toy telephone of string and tomato cans. The downward motion stopped as last careful checks and last minute adjustments were made.

Peering upward the underside of the ocean surface looked to Barton like a greatly agitated ceiling—a sight that is a continual delight to divers. Finally, all arrangements were complete topside and the sphere started in earnest on its downward journey to mysterious regions below.

Green light flooding through the ports illuminated the



The Benthoscope being raised from a test dive. The wooden vanes were used to minimize twisting of the sphere which caused great trouble with snarling of the cables. (Photo courtesy Allan Hancock Foundation, University of Southern California.)

blackened interior of the sphere. The light decreased as the sphere descended and at a depth of 200 feet there was a noticeable change in color: the green had faded a bit and the light was now a greenish blue. The water acts much as a filter used on cameras — it absorbs some colors and not others, and this effect varies with depth. The reds are the first to go, then the greens, then the blue.

At 460 feet Dr. Nelles heard over his earphones and the rest heard on the loudspeaker, "It's dark enough now so I can see the first outlines of fish with their brilliant sparks — it's pretty dark down here but I don't see the fireworks I saw yesterday [referring to explosive displays of phos-

phorescence]—there are a lot of lantern fish passing by now. Now the fireworks are really starting! . . . There's a 'bishop's mitre' fish! Will you please look him up in my biology book? I want to compare them when I come up. . . . There's a creature that looks like a long pipe with a row of lights on it . . . tentacles of an octopus just dragged by the window and broke into a shower of sparks."

Six hundred feet: the light had almost failed, and yet there seemed to be a great amount of light. Closer scrutiny revealed that what light remained was a deep luminous blue. Of this strange phenomenon Beebe had written in describing a bathysphere dive, "It seemed bright, but was so lacking in actual power that it was useless for reading or writing."

At a 1000-foot depth the sunlight was gone except for a ghostly reminder difficult to describe. Creatures living in these depths are creatures of eternal darkness. The blue had changed to a blackish blue and thence to black—the violet apparently had already been absorbed.

1500 feet: "It's just like sitting in an icebox. I'd hate to touch the walls here. . . . I'm wrapped in a blanket now."

2500 feet: "I see a barrage of luminescent shrimp spiraling outside the window. They give off a flash when they hit. . . . This is an *unbelievable* world."

4000 feet: The previous trouble with the power cable returned as suddenly the floodlights went out. "This may be deep enough," said Barton. Flashes from animal lights appeared.

"Everything's all right topside," Nelles spoke reassuringly into the microphone.

"Well, I guess I might as well go down another 500 feet. But it's awfully cold and I'm drawing my blanket tight around me."

At 4100 feet Barton called up, "I won't look at the window right now because it gives me a rather unsteady feeling." The strange sensation of motion of the ball noticed on other dives had returned.

At 12:48 P.M., a depth of 4500 feet was reached, almost 1500 feet deeper than the Barton-Beebe record in the bathysphere.

"I'll look now. . . . There's a triangular light with a glow behind it and a line in front. . . . I've got my face right in the window now. . . . I'm going to change my position — it's very uncomfortable. . . . It's the nervous strain, eye-strain from the movement of the organisms." For eight minutes Barton dangled in the abyssal darkness.

"I don't want to do anything foolish. I guess I'd better come up." Without power for his floodlights Barton felt he could do nothing but watch the lights of the fish without being able to identify them.

The long haul to the surface began. Almost a mile of cable was out, the power of the winch was limited and thus was the speed of ascent, but the really time-consuming thing was stopping every hundred feet so that a crewman could cut the lashings holding the power and telephone cables to the main cable. Without this support the power and communication cables would have broken of their own weight. Now they had to be hauled in and laid out on deck in an orderly figure-eight to avoid snarls and kinks.

At 2:12 P.M. the ball broke the surface and was plunked safely down on the steel deck of the big barge. None too soon, for whitecaps were appearing all about, indicating winds too strong for comfort. Dr. Nelles cautiously unscrewed the large brass bushing in the center of the circular door through which the telephone cable leads

passed. By telephone he had received assurance from Barton that the pressure within the sphere was very close to atmospheric pressure. Opening the door with a great differential of pressure would cause great discomfort, even a case of the "bends" for Barton. If the barometer within was not functioning properly, this could easily happen. A sudden whistling of air would herald excruciating pains for Barton. Dr. Nelles grinned as the last turns dropped the plug into his hands with only a slight noise. Once the great nuts were removed, the door was lowered to the deck and Barton emerged with teeth chattering. He was almost bent double by his long stay under refrigerated conditions. With scarcely a well-earned grin of satisfaction at a job well done and only a perfunctory acknowledgment of congratulations, Barton began piling cables, tightening bolts, making plans for the next dive — which has not taken place. The man who had just dived deeper than any man had ever gone before, who had seen things no other man had ever seen, was too busy to be bothered as he picked up an armload of instruments to get them out of the salt spray flung by the rising wind.

THE BENTHOSCOPE

We have heard of the call of the sea, that irresistible urge that drags men back from the comparative security of solid land to the perils of the deep. Apparently the depths of the sea have just such an influence on the handful of people who have tasted of the unbelievable wonders of the black depths. Or so it worked with Otis Barton. The experience of going to a 3028 foot depth only sharpened his desire to go a mile deep.

The old Bathysphere, of course, wasn't the vehicle for a ride to depths of a mile. Careful design calculations indicated that it was liable to be crumpled like a bit of waste

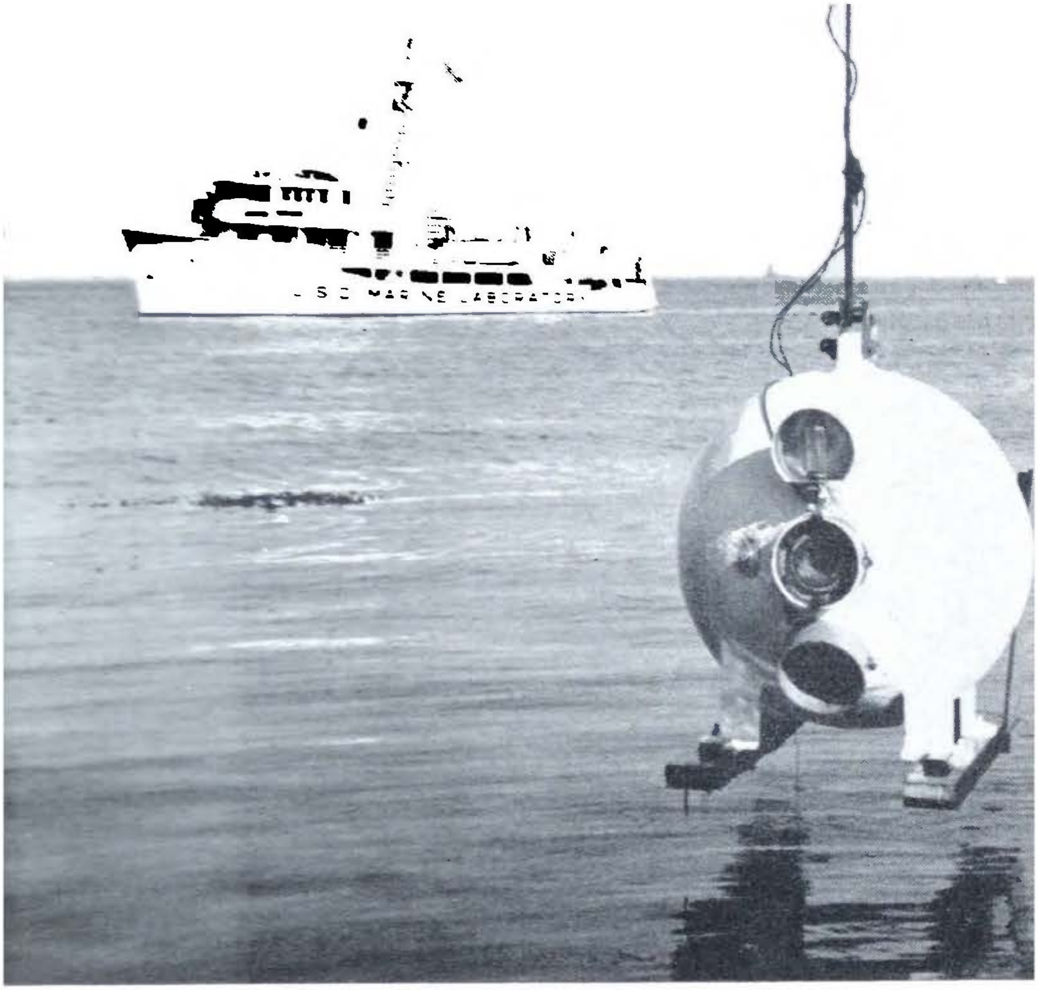
paper at a depth around 4000 feet. New materials, new designs, new ideas should be built into this new diving sphere. To differentiate it from its illustrious predecessor, it was dubbed "Benthoscope," the Greek root words meaning literally, "to view the depths of the sea."

Otis Barton designed, built, financed the Benthoscope. It was cast of special steel in Roselle, New Jersey, then shipped to the West Coast where preparations for a series of dives were being made.

It is not surprising to find the name of Captain G. Allan Hancock linked with a venture of this sort. It is recalled that he made possible Sir Charles Kingsford-Smith's record-breaking flight in the Southern Cross to Australia in 1928, and anything having to do with pioneering in scientific oceanographic work would be almost certain to attract his attention. The Hancock Foundation for Scientific Research of the University of Southern California was actively engaged in this deep dive in the search for better equipment for studying the depths of the sea. The machine shops and laboratories of the Hancock Foundation were devoted to this project, as well as the Marine Laboratory Ship, Velero IV, which served as the mother ship for the diving fleet.

The Benthoscope is a steel sphere of 57½ inches outside diameter, 3½ inches greater than its prototype, the Bathysphere. An added half-inch of steel wall thickness in this highly advantageous spherical shape increased the ultimate depth from 4000 to 10,000 feet. This increased the weight to 7000 pounds in air and 2600 pounds in water, requiring heavier hoisting equipment, special cables, etc.

The cable used was composed of 504 steel wires woven in a special way to minimize twisting when stretched because such twisting tangles the power and telephone cables around the main cable, to say nothing of making the occu-



The Benthoscope is a sphere of cast steel designed to withstand the pressure at a depth of 10,000 feet. (Photo courtesy Allan Hancock Foundation, University of Southern California.)

pant dizzy and to make observation difficult. This cable was subjected to a test load of 10,000 pounds by the manufacturer, and at the Allan Hancock Foundation Laboratories a test to destruction broke the cable at 30,000 pounds.

PRESSURES AT GREAT DEPTHS

Atmospheric air pressure results from the weight of a column of air from the surface of the earth to the top of the atmosphere. The force this column of air exerts upon a square inch of surface of the earth is actually the weight of this column of air one inch square and many miles high. This atmospheric pressure is 14.7 pounds per square inch

at sea level. Water is much heavier than air so we would expect the pressure to build up much faster as we descend into the sea. Actually, for every foot we descend beneath the water surface, the pressure is increased approximately one-half pound per square inch. Thus at a depth of 6000 feet the pressure is 2664 pounds per square inch, and the total force of the water on the Benthoscope would be 27 million pounds. If a human body were subjected to the water pressure at this depth, a total force of five million pounds would crush out all life.

FRESH AIR A MILE DEEP

Isolated in a solid steel sphere thousands of feet below the surface of the ocean, a certain lack of fresh air and ventilation would be perfectly understandable. But the human frame demands rather large quantities of just that. Fortunately, modern science comes to the rescue with a very effective air purification system.

In normal breathing, the lungs remove oxygen from the air and as waste products, carbon dioxide and water are exhaled. In the Benthoscope oxygen is released from storage cylinders to replace that which is burned up by the human body, and the carbon dioxide and water are absorbed by a white, chalky substance called soda lime held in screen frames so that a maximum surface is presented to the foul air in need of cleaning. To speed up this purification process, a small electric fan circulates the air. In case of power failure, this circulation can be accomplished by a hand fan. Sufficient oxygen and soda lime are carried to sustain life for a period of six hours.

A CLOSE SHAVE

The night before the deep dive as we were sitting on the afterdeck of the Velero IV, I asked Otis Barton what

had been his closest call in his many years of sphere diving. Without a moment's hesitation he told of a dive he and Dr. Beebe made in the Bathysphere off Bermuda. Everything seemed to be going well as the sphere was lowered to a depth of around 2000 feet. In the darkness Dr. Beebe was wholly preoccupied in his gleeful observations of organisms never before viewed by man, while Barton vacillated between looking out another port to confirm observations and glancing at the pressure gauge, the fan, and the other details upon which their lives hung. A slight noise caught his attention. It seemed to come from the top of the Bathysphere. He snapped on his flashlight and to his horror he saw what appeared to be a giant snake entering the sphere! The huge black form writhed sinuously as it crawled into the sphere.

For a split second Barton gazed in questioning amazement, and then it dawned upon him just what was happening. In the Bathysphere, in contrast to the Benthoscope, the power cable entered the sphere and the spotlights were inside. The cable entered through a packing gland at the top of the sphere and because of the excessive pressure of the water at that depth, the packing gland was not holding the rubber-covered cable tightly enough and the cable was being forced into the sphere! Two men, a spotlight, oxygen tanks and other equipment were already in this sphere; how long would it take for the writhing rubber creature to fill it completely? Would the power cable break under this great stress allowing the occupants to be crushed with the great pressure of the water that would thus be allowed to enter?

Within seconds the order was given to haul up the sphere, and a frantic race with time and pressure began.

"We won that race," said Barton wryly, "but I would

hate to go through such an experience again." The Benthoscope spotlight is *outside* the sphere!

The insatiable mind and the indomitable spirit of man will probably not be satisfied for long with Barton's dive to a 4500-foot depth. As long as the depths of the ocean remain unexplored there will be a yearning to explore them just as soon as technological advances make such exploration possible. Barton has found the competition in this business exceedingly light, but it is just a matter of time before these pioneering efforts will be topped by others.

THE DIVING SPIDER

When it comes to pioneering in diving, however, man will have to take off his hat to a tiny spider, *Argyroneta aquatica,* the European diving spider. This spider is an air breather, even as man, and yet it chooses to live beneath the water in a special biological benthoscope of its own construction.

Many of the spiders are called "water spiders" because of water activities more or less incidental to their habits of living in moist localities. However, such an application of this term seems out of place when the life activities of these spiders are compared to those of the true diving spider, *Argyroneta aquatica.* This remarkable spider can live for weeks in a diving bell of its own construction, live on aquatic animals, mate, lay eggs, raise the young and hibernate throughout the winter in a specially constructed house beneath the surface of the water. Truly this amazing creature has undisputed claim to the title of "Water Spider" or "Diving Spider."

Throughout Europe and temperate Asia, the diving spider *Argyroneta* can be found in fresh water ponds and sluggish streams choked with aquatic plants. Their bubble-

The European diving spider (*Argyroneta aquatica*) is an air-breathing spider, like others, but chooses to spend practically all of its life below the water surface.

like diving bells can be found anchored between rootlets and the matted threads of algae, and along the stalks of water plants.

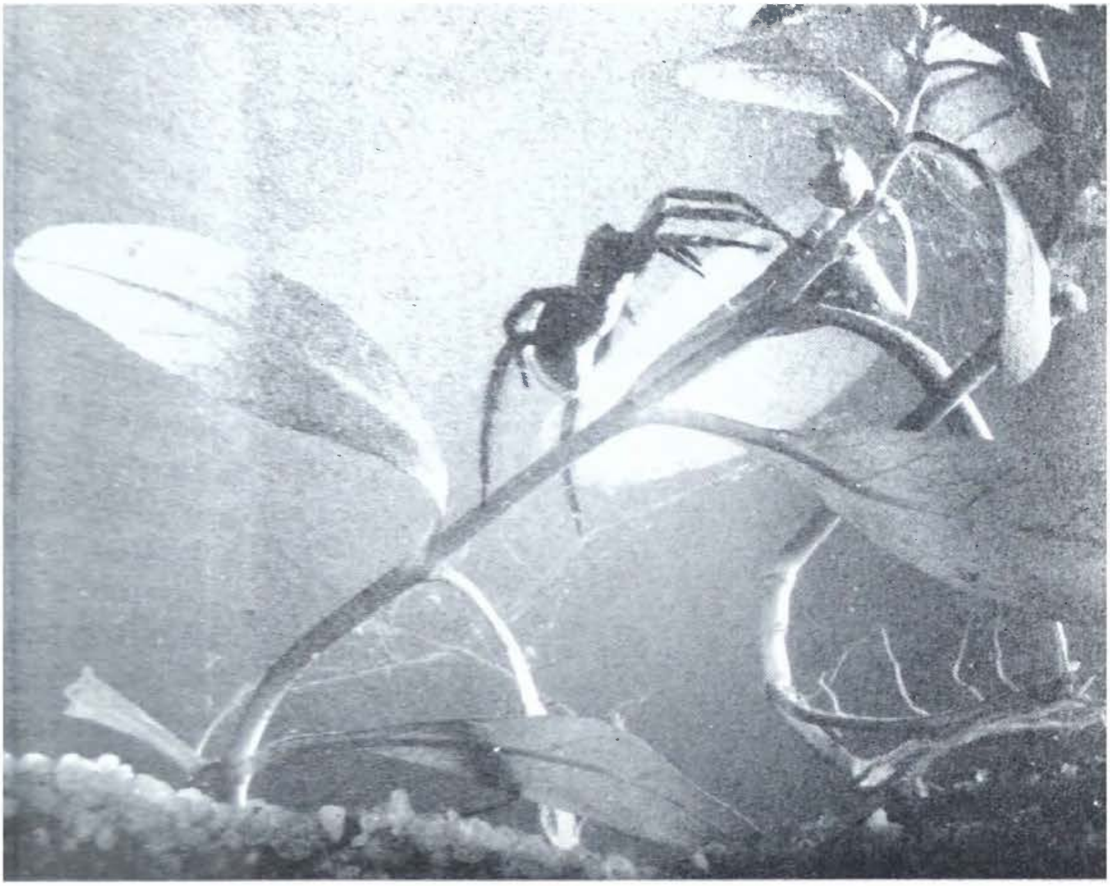
Such outstanding performance would seem to be more appropriate to a gaudy spider, or to one of unusual physical appearance, but such is not the case. *Argyroneta,* in spite of its remarkable skill under water, is a very dingy, ordinary-looking spider. Its color is dark brown and its size approximately a half-inch across. The male is larger than the female, a rather unusual situation in spiders, spanning about two-thirds of an inch across when fully grown. *Argyroneta's* drab appearance out of the water gives no

promise of the jewel-like appearance when submerged, for upon entering the water it takes down a beautiful silvery bubble of air on its abdomen. Although the cephalothorax is bare both under and above, the abdomen is densely covered with blackish hairs. The legs are also equipped with long hairs which assist in the vital business of supplying air to the house beneath the water surface.

Although spiders have eyes, mouth parts, etc. on the front end where normally expected, they do their breathing through spiracles on the underside of the abdomen. They are true air-breathers and, as such, need their constant supply of air. How this is accomplished in *Argyroneta* is a thrilling story. The instant the diving spider submerges, a shiny bubble of air is caught and carried by the hairs of the abdomen. Thus the spiracles open into the bubble and find an adequate air supply even though the spider is submerged. As the spider crawls out of the water, the bubble disappears.

To appreciate what this spider does, consider what man would have to do to equal it. A large bubble of air surrounding his head would have to be picked up as the swimmer dived into the water. This large bubble, like the helmet of a space suit, would supply air for breathing and would allow the man to remain submerged days, or even weeks at a time. Add to this the ability to fashion a diving bell large enough for his whole family and to fill it with air by sharing bubbles carried from the surface, and we have a fair picture of the accomplishment of *Argyroneta.*

The diving spider is the only spider that can swim freely about in the water without holding on to submerged objects as the roots and stems of water plants. It swims about with vigorous action of its legs with an exaggerated walking motion. This gives the spider a groping appear-



The diving spider (*Argyroneta aquatica*) stringing guys and stays for its new house among the aquatic plants beneath the water surface. In this bubble house these spiders live, mate, and rear their young.

ance, but good progress is made. Usually the diving spider swims with back downwards, although this is not always the case. The long lateral hairs of the legs greatly assist as propelling agents.

DIVING BELL CONSTRUCTION

The construction of the house is a marvel of engineering skill and the silk-ejecting spinnerets are the principal tools. The spider spins a horizontal membrane of fine web somewhat less than an inch in diameter and securely fastens it to nearby vegetation by a series of tie-lines. When this tedious and painstaking work is completed and the sheet

is finished and firmly anchored, the spider goes to the surface for an extra large bubble, laboriously hauls it down to the level of the newly constructed sheet, and releases the bubble under it. The bubble is caught by the membrane and the buoyancy of the air stretches the sheet into a dome-shaped vessel open downward. More bubbles stretch the dome upwards even more until finally the diving bell is finished — a fine air-filled house in which the spider can set up housekeeping and start raising a family safe from the unfavorable influences of the world above the water surface. More guys and stays are added as the diving bell is nearly filled to counteract the strains due to the buoyant force of the captured air within the sheet. This house is occupied by the resting spider in a sloping position with feet upwards. Usually only the abdomen is inside the bell, the cephalothorax and the anterior two pairs of legs remaining in the water.

The diving spider can remain in this house for weeks, the length of time depending upon the degree of activity and other factors. The excess carbon dioxide is dissolved by the water forming the boundary of the house, and a certain amount of oxygen from the water replaces the carbon dioxide given up. Air conditioning the bubble is not left to this effect alone, however, for the spider periodically cuts a hole in the top of the dome, allowing the air in the house to bubble to the surface. After an easy repair job, the membrane is again filled with bubbles of fresh air which are brought from the surface.

One of the many mystifying things surrounding the functions of the diving spider is just how the spider manages to leave any air in the diving bell at all. As the spider crawls out of the air in the bell, the bubble immediately re-forms on his abdomen. Yet he had a bubble on his

abdomen as he entered, so how is air left in the bell? Obviously the bubbles brought down must be larger than those taken out or there would be no net gain in air in the house. The answer apparently lies in the use of the legs in holding the large bubble. The increase in surface afforded by the legs and their combs of hairs apparently provides the means of holding the larger bubble in descending, while the assistance of the legs is not necessary as he emerges from the diving bell to swim about the water with a smaller bubble adequate for its own immediate needs.

THE DRAGLINE

The spider itself is heavier than water, but with a large bubble of air on its abdomen it is a constant fight to stay submerged. *Argyroneta,* in its specialized aquatic way, depends greatly upon the trailing of a thread of silk, or a so-called "dragline." The literature records the conjectures of many scientists concerning the existence of the dragline. Nielsen carefully records observations of the descent of the diving spider with a large bubble of air which seems to be explained only on the basis of a dragline stretched like a rubber band. The difficulty is that, under normal circumstances, no thread can be seen. Maeterlink did not seem willing to accept the invisible thread theory because his observations did not bear it out. In the Moody Institute of Science laboratory, however, such threads have been seen. In fact, motion pictures showing the spider descending with a buoyant burden of air clearly reveal the presence of a dragline by which the spider receives assistance in the descent. Whether this is in a "rubber-band" or a "reeling-in" manner, we cannot say.

Apparently the index of refraction of the silk from which the dragline is made is almost identical to that of

The quicksilver-like bubble clinging to the abdomen of the European diving spider supplies air to the spiracles through which the spider breathes.

water to account for the great difficulty in seeing the dragline in the water. It was only through following a photographic procedure of using a strong backlight that this dragline was made visible enough to photograph on color film.

CAPTURING THE BUBBLE

The act of renewing the quicksilver-like bubble of air on the abdomen of the spider is a remarkable procedure. When the time comes for an ascent for another bubble, the spider goes up either by swimming, crawling along stalks or leaves, or up a dragline. It ascends head upward, but just beneath the surface it does a flip which places the

ead downward with the abdomen out of the water. At his stage the procedure is somewhat different for renewing he bubble for its own sustenance than for obtaining a big ubble to release within the diving bell. For a bubble for ts own immediate use, the spider may remain with the tip f the abdomen, the spiracles, and the spinnerets out of he water for a few seconds or even several minutes. When stock of air is being obtained for deposit in the diving ell, however, the whole abdomen as well as the posterior air of legs is raised out of the water, the two legs forming n arch over the abdomen. The third pair of legs may be raced against the underside of the water surface. The two nterior pairs of legs stand ready to provide the initial wimming thrust once the bubble is captured. This bubble apture is accomplished in a flash as the spider pulls itself lown through the surface film of water at the same time s the posterior pair of legs is moved in such a way that more open arch is formed. Once through the surface ilm, the large bubble caught by the hairs of the abdomen s held by the posterior legs with their brushes of hairs. or a large bubble, the next pair of legs may also be called pon to assist in holding the bubble which now is straining t the moorings of the hairs on the abdomen and brushes f hairs on the posterior legs.

The descent against the buoyant force of the large bubble s accomplished by the swimming motions of the legs and he dragline and no time is lost in getting down because f the great danger of losing the precious bubble. Sometimes the bubble is lost on the way down, but usually the pider reaches the diving bell where the bubble is released. weeping motions of the legs along the abdomen then elease more tiny bubbles and extensive preening keeps the ll-important hairs in good condition.

Scientists for the past 150 or 200 years have pondered the question of what makes the water stick on the abdomen of the diving spider. In 1787 Lignac postulated that the hairs on the legs and the abdomen were coated with a grease or varnish which made the water cling to them. Maeterlink has perpetuated this idea, although later scientists have discounted it. In 1900 Wagner and in 1907 Bail advanced the idea that the abdomen was covered with a layer of web. It is understandable how this concept developed because within the diving bell much of the diving spider's time is spent in making his "toilet" by sweeping its posterior tarsi along the abdomen after having swept them across the spinnerets. Apparently this procedure has much to do with the water-holding ability of the abdomen. The fact that the hairs on the abdomen are of varying length and have hooks on the end are undoubtedly contributing factors also. It is well known that upon occasions these diving spiders lose their ability to hold air on their abdomens and at such times they really take on a "drowned rat" appearance. When this happens they climb out of the water to a floating object or, in an aquarium, hang above the water line from a bit of silk attached to the vertical glass wall. Their alarm at such times of indisposal reminds one of the duck which had been dipped in a detergent trying to swim at periscope depth with a covering of feathers that were for the first time wetted by water.

Nielsen recounts the calculations of scientists (principally Schollmeyer and Wefelscheid) to estimate the length of time a "charge" of air should last a diving spider. Obviously, this length of time must depend greatly upon a number of factors such as the amount of activity of the spider and the degree of interchange between the air of

the bubble and the air in the water. The amount of air dissolved in the water and the extent of the surface are also vital factors. During the winter the spider hibernates for months at a time and during this time he must, doubtless, depend heavily upon oxygen from the water which is released by plants.

LIFE IN A DIVING BELL

The food of *Argyroneta aquatica* is largely water mites captured in the water. The hunting is done at night and the water mites are hauled back to the diving bell to be digested. The action of the saliva in the mouth would be well-nigh impossible in the water. In captivity, the diving spider readily accepts fluttering moths tossed on the surface, laboriously hauling them down into the water where they are trussed up with silken threads and securely anchored to the branch or leaf of a plant.

It seems incredible that an air-breathing creature such as the European diving spider would elect to raise its family in a small bubble under water. However, the remote confines of this silvery bubble in some way better meet the needs of the spider in feeding, molting, mating, and rearing of the family. Sometimes the male shares the same bell with the smaller female at pairing time, but at other times the male spins a smaller bell near his mate, fills it with air and joins it to the bell of the female by a silken tunnel. After mating, about 75 to 100 saffron-colored eggs are deposited in a tough sac in the "attic" of the diving bell. After about three weeks the spiderlings hatch and move down from the attic to the lower part of the bell where they stay for another 16 days or so. During this brief growing-up time they stay within the bell, but these babies then venture out on their own, expert swimmers

from the start and bent on building their own diving bell.

In the fall the diving spiders move to deeper water in preparation for the winter. Usually a new and different house is made in which to spend the winter. Quite frequently this more secure house is a closed sac built in an abandoned snail shell. The water in such a shell first has to be removed, and this is done by displacing the water by air laboriously carried down. To prevent the snail shell from floating away it is weighted down by bits of debris from the bottom of the pond. Once the new web house has been built in the shell, the spider encloses itself and remains dormant throughout the winter.

THE BIOLOGICAL BENTHOSCOPE

Extensive planning, careful design, a fabulous amount of preparation and a great deal of fearful expectancy are a necessary part of a Benthoscope dive. All of this frenzied and complicated activity accompanying one of man's dives is made to look quite silly as one sees *Argyroneta* pick up a bubble with a mere flip of its tail and swim leisurely about. Providing for this spider's needs in this unusual way is an eloquent testimony to the wisdom, the power, and the providence of God. It will not detract from the credit due Otis Barton to give God His due in this matter — for the biological benthoscope must be awarded the prior claim.

Chapter 8

SNAKES AND SNOOPERSCOPES

SNAKES WILL PROBABLY never be particularly popular creatures, yet knowing something of the wonderful organs id abilities of these lowly members of God's great econny will help to bridge this chasm of misunderstanding.

I used to feel an aversion toward bats as unreasoned as e woman who fears they might become entangled in her ir, but a better appreciation of their wonderful "radar" uipment for avoiding obstacles and detecting insects has used a revolution in my attitude toward these flying ammals. I now stand fascinated when I see a bat at dusk osing in on insects like a Black Widow radar night fighter osing in on an unsuspecting enemy aircraft. Where once e vermin on bats was so repugnant to me, with this more preciative view I found myself deep within the oppresve darkness of a large bat cave in Texas, where the owdery guano covering the floor was alive with a cloudy yer of jumping vermin several inches high! So absorbed as I in the bats I scarcely noticed the vermin.

Snakes rate even lower in popularity than bats as far as e average person is concerned, but perhaps an underanding of some of the almost unbelievable organs of the it vipers will give us a new appreciation, not only of the reature itself, but also of the Creator.

WHAT ARE PIT VIPERS?

The New World vipers are distinguished from all other snakes by the fact that they have a deep depression, or pit, between the nostril and eye on each side of the upper jaw. This family of snakes, the Crotalidae, includes the common poisonous snakes such as rattlesnakes, moccasins, and copperheads. In fact, if you want a clue as to whether a snake is poisonous or not, look for the pits. If the snake has facial pits, beware! The pits are so shaped that if they were headlights, the light would be thrown well forward and slightly to each side. The pit is divided into an outer and an inner chamber by a membrane, or fold of skin.

EARLY IDEAS OF PIT FUNCTION

In 1824 Desmoulins noticed the rich supply of nerves leading from these pits to the brain. When physiologists see such a supply of nerves they strongly suspect an important sensory organ of some sort, but Desmoulins did not know what useful purpose these pits served. He made a guess that they were probably olefactory organs, not knowing how the keen sense of smell of pit vipers and other snakes was a result of the combined action of the darting tongue and an organ of smell in the roof of the mouth. The darting tongue samples the air and brings into the mouth volatile chemical compounds of the sort that stimulate our organs of smell. The tongue then lays this solution on the Jacobson's organ in the roof of the mouth which sends appropriate messages to the brain. The tongue merely samples the air and brings the samples back to the organ for analysis. Desmoulin's guess was not illogical under the circumstances, but it has since been proved to be incorrect. There were many other guesses down through the years. Some scientists thought the pits were

Dr. Raymond C. Cowles, professor of Zoology at the University of California at Los Angeles, holds a Red Diamond rattlesnake for the Moody Institute of Science camera.

auditory organs, and the presence of the membrane would seem to lend credence to this theory. However, the resemblance to the ear ends here and why should an eardrum be so well supplied with nerve endings? Others suggested that the pits were tear ducts to allow access of air to the poison sacs. At least one naturalist thought the pits were glands, and another suggested that they were organs of "sixth sense." Many other suggestions were made, such as thinking that the pits served some tactile function.

THE WORK OF G. K. NOBLE

There is no surer antidote for a century of speculation on a subject than a few years' work in the research laboratory. Most of the speculations came from European scientists who had little opportunity for firsthand investigation, for the pit vipers lived only in the New World and in limited areas of Asia. It remained for Dr. C. Kingsley Noble, working in the experimental laboratories of the American Museum of Natural History, to attack the problem in a sensible, experimental way. His work demonstrated beyond a doubt that the pits were thermal receptors to detect the presence of warm-blooded prey and to assist the snake to strike its prey with precision in total darkness. Dr. Noble used a machine which swung cloth covered electric light bulbs past the snake under test. He used cold light bulbs and warm ones in a random fashion. His amazing disclosure was that a temperature difference of 0.2°C. was sufficient to excite the pit viper to strike. Not only were the pits thermal organs, they were extremely sensitive ones! He showed that the odor from a chilled but dead mouse would excite much tongue flicking, but a warm dead mouse would elicit a strike. This emphasized the keen sense of smell such snakes have, and showed the

dependence of the snake on the thermal receptors for night hunting. Rattlesnakes trail their prey by means of their sense of smell through the darting tongue.

Dr. Noble demonstrated that with all the snake's sensory organs but the pits put out of commission the snake could strike with terrible precision. However, filling the pit organs of such snakes with collodion rendered them helpless. In the absence of vision the warmth of the prey is the most important stimulus to the snake and provides it with sufficient information to locate prey and strike accurately in the dark. The membrane in the pit apparently serves to give the snake an acute sensitivity to air movements associated with moving objects, but the response to the combination of warm objects which move predominates.

LABIAL PITS

Noble also worked with snakes of the family Boidae such as the boa and python. These do not have the well-pronounced pits of the Crotalidae but they do have a series of sensory labial pits which are comparatively shallow depressions in the scales of the upper and lower jaws. These were also found to be thermal receptors, although they do not have the membrane and hence do not respond to air movements.

HEAT SENSITIVITY IN LIZARDS

Definite knowledge that the true function of the pit organs had to do with temperature suggested the answers to many problems concerning the relation of reptiles to the heat of their environment. Finding reptiles in the desert makes us suspect that they are especially resistant to heat. Such is not the case, for they are very sensitive to heat. Dr. Bogert and Dr. Cowles have shown that the open sun quickly kills such creatures. They released a Granite Night

Dr. Raymond C. Cowles (left) holds a Red Diamond rattler while Dr. Theodore H. Bullock (right) administers an anesthetic preparatory to study of the infrared pit organs.

Lizard in the shade and it promptly fled in panic to the open sunshine of the desert. There it stopped, opened its mouth, and died. The canyon-dwellers are also extremely sensitive to heat. A Rock Uta was paralyzed in two minutes in the sun, and a Green Scaly lizard died in even less time. What a strange situation — desert creatures that cannot stay in the sun more than a couple of minutes on pain of death! The color change of lizards is very important in their resistance to heat. Man puts on white clothing in the summer because it reflects the heat and makes him cooler. In the winter, dark clothing is worn. The color changes in the lizards accomplish this same purpose, but

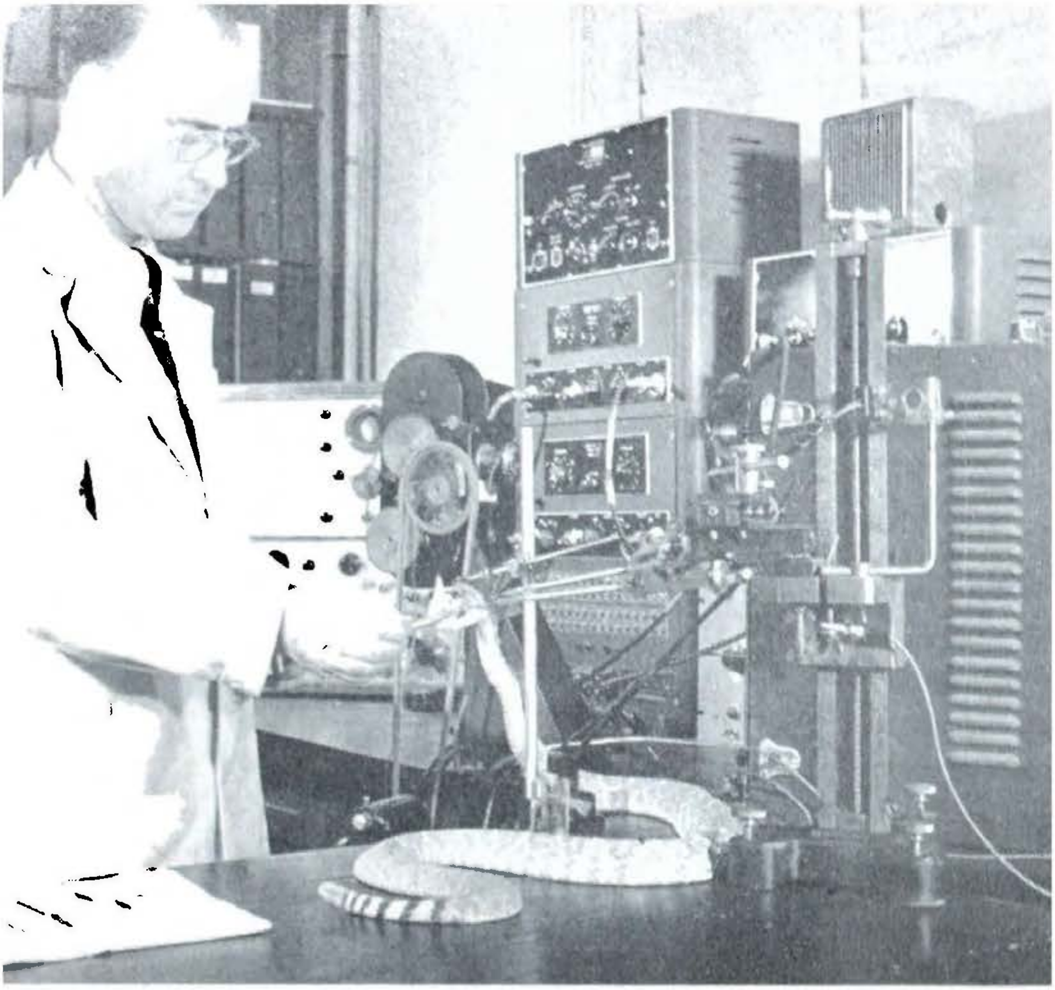
these will not act fast enough nor is their effect sufficient to compensate for such abnormal changes as a night lizard being placed in the open sunlight.

HEAT SENSITIVITY IN SNAKES

It has been demonstrated that reptiles cannot endure temperatures greater than 120°F. for long, and the desert floor exceeds this value much of the time. Crocodiles can be killed by exposing them to the sun. The sidewinder rattlesnake maintains its body temperature very close to 92°F. by the expedient of moving to cooler or warmer locations for it does not have all of the automatic thermostatic equipment that our human bodies have. Snakes also do not have the ability to change their body color appreciably. For these reasons many snakes forage for food at night. The facial pits fit into this picture as they enable the snake to detect and strike its prey in the dark. Experimental work suggests that the facial pits serve as temperature detectors both in the absolute sense of determining the environmental temperature like a thermometer, and as a differential instrument which compares the temperature of the snake's body with that of its environment.

THE BULLOCK-COWLES EXPERIMENTS

Dr. Theodore H. Bullock and Dr. Raymond C. Cowles of the Department of Zoology of the University of California at Los Angeles have applied modern neurological techniques to the study of the pit organ. They utilize the principle that nerve impulses from sensory organs are electrical in character. They anesthetize a rattlesnake and lay bare the bundle of nerves leaving the pit organ. To this bundle they touch platinum electrodes connected to the input of an amplifier. The amplifier then operates an indicating device such as a cathode-ray oscilloscope, a sound volume indicator, a loudspeaker, or a recording instrument.



Dr. Theodore H. Bullock, University of California at Los Angeles, holds a lighted match before the face of the anesthetized Red Diamond rattler. The heat from the match results in great electrical signals from the pit organ nerves.

The effect of various heat stimuli can then be studied and measured.

Let us listen to the loudspeaker as the snake is subjected to nothing but the normal environment of the room. A sound very similar to static on the radio is heard which is actually a barrage of independent nerve impulses. This background noise corresponds to the ambient temperature of the room. As the hand is brought up before the pits the sound from the loudspeaker increases to a roar. When the hand is removed the sound decreases to normal. A piece of ice brought up to the pit makes the sound disappear momentarily, but it slowly returns even though the ice

remains in position. In other words, there is an adaptation effect which takes over after the initial upward or downward surge. Striking a match in front of the pit makes the noise increase, but inserting a piece of glass between the match and the pit nullifies the effect of the heat. The glass allows the visible light of the match to pass through but the infrared rays are absorbed, demonstrating that it is not the visible rays that provide the stimulation. A further precaution against stimulating the snake by visible light rays is blindfolding its eyes.

Dr. Bullock and Dr. Cowles demonstrated the threshold of sensitivity of the pits by showing that rattlesnakes can detect a human hand at about twelve inches. A glass of water 1°C. above room temperature placed near the pit, will also give a just noticeable reaction.

THE SNOOPERSCOPE AND THE SNIPERSCOPE

Even before World War II military officials recognized the value of secrecy afforded by invisible infrared devices and research work was authorized to explore this field. The Radio Corporation of America did most of the early work in this field, developing the special vacuum tubes by which the infrared image was converted into a visible light image that the eye could see.

The Snooperscope is typical of these devices. By means of monocular or binocular optics, the infrared light reflected from the scene being viewed was received by an optical system and thrown upon a special photo-electric screen which was sensitive to these rays. The electron image thus formed was made to impinge upon a fluorescent screen which, in the case of the Willemite screen, reproduced the scene in a brilliant green light. As the floodlight used beamed out only the invisible "black light," true night

vision was thus afforded. A similar device mounted on a rifle was dubbed the Sniperscope and was effectively used in the war. A helmet-mounted binocular device enabled a driver of a motor vehicle to travel 30 miles an hour in total darkness by the "black" light from a pair of auxiliary headlights having black filter lenses.

These developments have been hailed as some of the greatest electronic advances of our time, but they operate on the same principle that the rattlesnakes and other pit vipers have been using from the time of creation. Thus once again man finds his ingenious invention anticipated by a lowly creature in nature. Even in the great inventions and developments which characterize this modern age, man does not have prior claim for, wherever he may delve, he finds that God was there first!

HOW IT FEELS TO BE BITTEN BY A RATTLESNAKE

Writing upon such a subject as "The Art of Sticking One's Finger in a Meat Grinder" would cast some serious doubts as to the mental alertness of the author. Realizing full well the similar risk involved in the present disclosure, it was felt that a description of such an experience might be of interest because it isn't everyone that can claim the dubious distinction of being bitten by a rattlesnake!

Dr. Raymond C. Cowles of the University of California at Los Angeles has been handling rattlesnakes in connection with his research work on reptiles for over twenty-five years. He has caught them in the desert, kept them in a glass cage in his office, and handled them in the classroom without a single accident to himself or to his students. He thinks nothing of picking up rattlesnakes (by a carefully prescribed method born of a healthy respect), holding them by the nape of the neck, and "milking" the venom from

their fangs by allowing them to strike a rubber hose. Nor are these debilitated or toothless specimens like the proverbial movie lion, but they are sidewinders which have more energy per cubic centimeter than many of their larger cousins, red diamond rattlers, or the spirited Pacific rattlesnake with its beautiful black coat.

While Moody Institute of Science photographers were capturing the fascinating story of the termal receptors of "pits" of the rattlesnakes on motion picture film, a three-foot black Pacific rattlesnake was out on the table. Tedious close-up photography designed to show the facial pits clearly had led Dr. Cowles to tape a four-inch section of split rubber hose about the neck of the snake so that he would be able to hold the head accurately in place. Earlier that morning the usual precaution of milking the venom had been taken. With the hose about the neck, the snake was unable to turn its head sharply about and bite the hand holding it.

About the middle of the afternoon, the particular sequence of scenes was completed and attention was turned toward obtaining some sound effects with the portable Minitape magnetic recorder. The rattles of this snake had been buzzing violently since the snake was removed from its glass cage hours before. The snake co-operated beautifully in continuing the buzzing while the recordings were made as I held the microphone within an inch of the rattles. Dr. Cowles made the suggestion that we might like to record the hiss of the snake as there was considerable doubt in the minds of some that snakes hissed at all. Before adequate preparations in restraining the head of the snake were made, I carelessly moved the microphone into position near the mouth of the snake and suddenly the snake struck the tip of my index finger. As I jerked

Dr. Raymond C. Cowles of the Zoology Department of the University of California at Los Angeles (left) holds a Pacific rattlesnake while the author records the sound of the buzzing rattles of this angry snake. (Minutes after this photograph was taken, the author was bitten on the index finger by this rattlesnake.)

my hand away it was already freed from the fangs of the snake. Dr. Cowles tore the necktie from his collar and applied it as a tourniquet around the finger and began to suck the wound vigorously, spitting the blood and venom from his mouth. After a few minutes of this he went after the snake bite kit which had been kept all these years for such a time as this, only to find that it was locked in a closet and that the janitor had taken the key with him on his vacation! A phone call to the emergency ward of the Santa Monica General Hospital alerted them to what was coming and away we went in a campus police car.

"What kind of a snake was it?" asked the police officer at the wheel in a sort of "do you think it will rain" manner.

"Rattlesnake," answered Dr. Cowles.

There was a noticeable stiffening of the man at the wheel, the siren started to wail, and the accelerator went to the floor board. Westwood Village is rated by UCLA students as a pedestrian's paradise, and a stretch of street to avoid if one is in a hurry, but all this was changed now as we shot down Westwood Boulevard. At Wilshire Boulevard the light was red, but we went through it to the tune of screaming rubber, moaning siren, and startled gazes from innocent bystanders. I began to worry, but it wasn't the snake bite that troubled me so much as it was the cars scurrying to the curb. Down the alley we went and the car slid to a stop at the entrance to the Emergency Ward. Two operating tables, side by side, were painfully in evidence as we entered, one of which was covered from head to foot with freshly opened cartons, bottles, hypodermic needles and the sheet of directions neatly flattened out. I reflected upon the number of times this doctor had probably had occasion to treat a rattlesnake bite here in a great metropolitan area

and agreed silently that the directions were doubtless a good idea.

The hamburger session was next. Apparently paragraph "A" of the instructions had read, "Remove all the meat from the bone" for he went to work with a scalpel in lacerating the flesh around the two tiny prick marks. Every effort was made to make the blood flow freely in a nice sanitary fashion, but finally the doctor also fell back on the effectiveness of the good old schoolboy trick of sucking the wound.

Then came the horse serum antivenin paragraph in the instructions. The doctor asked me if I were allergic to horse serum and I said that I was not as far as I knew, that six months before I had received almost every innoculation in the book in connection with a trip to the Pacific Islands. With this last possible barrier removed, he went to work with great vigor in sticking the needle into the finger and pushing the plunger as long as antivenin would flow from the needle, moving to a fresh spot and repeating the performance. After about two dozen such punctures, the doctor held up my bloated finger, wrinkling his brow quizzically.

"The directions said to inject 15 cubic centimeters of antivenin in the vicinity of the wound." There was a moment of silence. "You know," he said as he looked again at the finger — twice its normal size, "I don't think one finger can hold 15 cubic centimeters!"

Perhaps the writer of the instructions had a mental picture of a nice beefy calf of a leg that would hold much more, but the doctor seemed to be satisfied that it was useless to pump in more antivenin when it just ran out again. The stuff was expensive. Satisfied that the spirit, if not the letter, of the instructions had been followed, I

was dismissed with a recommendation to lie quietly in bed until the next day.

The next morning as we opened the door of Dr. Cowles' office to finish the photographic work we were greeted with a fierce and animated buzz from the cage. Had the little black beauty recognized me? It was a relief to see that the ugly rumor that the snake had died was untrue! Fighting back a rather startling impulse to bite his rattles off, I wound the camera with my left hand and selected a long focal length lens that would place *maximum* distance between camera and the subject which Dr. Cowles had just placed on the table with his handling hook.

"Too bad you didn't get pictures of the bite," my not too sympathetic colleagues said as they tried to pin a hastily contrived purple heart on me.

The bird with the crew haircut, the baby Laysan albatross or white gooney.

Chapter 9

BOOBIES, GOONEYS, AND AIRPLANES

NO ONE WOULD QUESTION that man received his ideas on flying from the birds. In the very earliest attempts at heavier-than-air flight man built wings patterned after the birds. During the 1890's Otto Lilienthal, a German mechanical engineer, made over 2000 brief soaring flights on wings patterned after the hawk. The momentous achievements of the Wright Brothers stemmed directly from Lilienthal's experiments. In watching the beautiful soaring flight of the gull, the albatross, or the frigate bird, it is easy to see that man still has far to go toward conquering the ocean of air. Fifty years of aviation have brought in many new things, but about the only ways we have exceeded the performance of the birds is in speed, load carrying ability, and noise. We are far from the navigational achievements of the Pacific Golden Plover, the structural efficiency of the frigate bird. What engine contrived by man can match the performance of the plover that flies 2000 miles nonstop, utilizing only a thin layer of fat for fuel? It is interesting to note that man is still turning to the birds for suggestions on improvements of his aircraft structures and performance.

MIDWAY ISLANDS

To appreciate the flying ability of the birds let us study these pioneers of flight on their home grounds. Nowhere

A baby black gooney on Midway Island sitting upon elbows and tail in its characteristic way.

on earth are there more interesting colonies of sea birds than Midway Islands. This tiny dot in the Pacific is about equidistant from the western coast of the United States and the Orient. It is also approximately at the half-way mark between the Marshall Islands and the Aleutians. Midway Atoll, about six miles in diameter, encloses two islands, Sand Island of about 900 acres and Eastern Island covering about 300 acres. In the early days there was no protection from the glaring white coral sand, but the activities of the Commercial Pacific Cable Company, Pan American Airways, and the United States Navy have changed all this. The planting of Ironwood trees and the encouragement of the spread of the native Scaevola shrub, a "beach

magnolia" having laurel-like leaves, have done much toward making these islands livable and beautiful.

The history of Midway Islands covers the gamut of shipwreck, murder, intrigue, and war. In 1859 Captain N. C. Brooks discovered these islands and took possession in the name of the United States. In 1867 formal annexation was accomplished, giving Midway Islands the distinction of being the first islands beyond its shores annexed by the United States. For many years after this, Midway was known mainly for the ships it wrecked. More ships have been destroyed by its reef than any of the other leeward islands of the Hawaiian group. There was the "General Siegel" (1886), the British bark "Wandering Minstrel" (1888), the sloop "Helene," the schooner "Julia Whalen" (1903), and the bark "Carleton" (1906). Many are the tales of violence among the shipwrecked victims, one party traveling 1500 miles in a small open boat to escape its inhospitable shores.

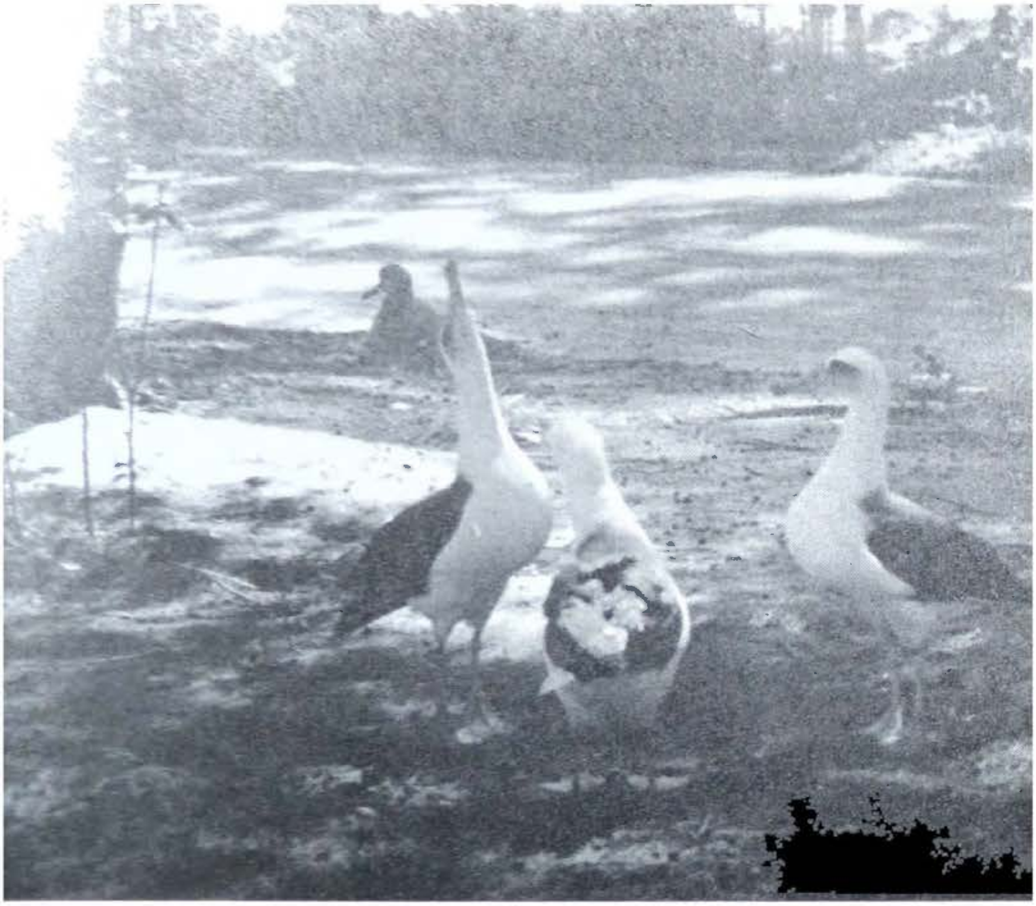
The sea birds of Midway have been witness to many attempts of man to encroach upon their domain. In fact, the plumage trade all but led to the annihilation of these birds. One party of poachers was caught with the plumage of a quarter million birds. Another group herded birds into a dry cistern to starve to death to reduce the layer of fat so that their job of cleaning the skins would be easier. Today the birds are carefully protected by the government.

While Pearl Harbor was being pounded by a Japanese force, Midway was being bombarded by a couple of enemy cruisers and several destroyers. Reinforcements saved the islands, but their strategic location led to the famous Battle of Midway fought for their control June 3-6, 1942. A major invasion force sent by the Japanese was met at sea by carrier-based planes and planes from Midway. The Japa-

The baby Laysan albatross is fed by regurgitation by parent bird recently returned from fishing at sea.

nese losses were so great in this battle that this became the turning point of the war. Nine months later when the author visited these islands the marks of the battle were evident on every hand. The wreckage of Zero fighters lay in the Scaevola bushes. Pock-marked concrete walls, a shattered water tank, and the fire-blackened skeleton of the seaplane hangar remained as a grim reminder of those days of violence and sudden death.

Many entertainers received citations for taking the risk of a trip to Midway during the war to help maintain the morale of the troops. However, no comedian or blues singer deserved such citation as much as the native birds.



A group of three Laysan albatrosses actively engaged in a late-afternoon dance. The birds have a repertoire of many discrete actions and sounds in which they engage in turn.

To the homesick men these birds became close friends and made life not only bearable but actually hilarious!

Approaching a group of ironwood trees on my first visit to Midway Islands in 1943, I was stopped in my tracks by the sight of a group of four white-breasted birds. They were in a circle facing each other performing an amazing dance. The bowing, the exultant honk from upstretched bill, the oh! so human waving of the head from side to side with a voice that eloquently said, "no! no! no!" the clapping of the bill, the coy response of tucking the bill under the wing, the pumping up and down by knee action were all strangely unbirdlike. At any given moment the

birds were each doing different things, changing off from time to time as if in a well-planned stage routine. These were the gooney birds I soon learned. These were nature's contribution to the morale of men assigned to live on this pile of sand. One cannot look upon such a performance of gooney birds and escape the conviction that God has a wonderful sense of humor! Although the gooney bird would be enough to bring immortal fame to these islands, it is only one of many birds having unusual features.

THE SOOTY TERNS

If one were to judge solely by numbers and noise, the sooty terns *(Sterna fuscata)* would easily win the distinction of being the most outstanding birds on the islands. These are beautiful birds about the size of a dove, but having a sleek and graceful streamlined appearance. The breast and neck are snow-white, and the back and the top of the head sooty black. The beak is long and pointed, and with great courage this bird will attempt to use this instrument on anyone trying to pick the bird up.

The sooty terns are aptly called the "swallows of the sea." It is estimated that there are about a half million of these terns at Midway, and they all congregate in a limited area of, perhaps, twenty acres in extent. Walking through this area is an experience never to be forgotten as the sky is literally darkened by the birds flushed from their nests on the sand, and one's ears are deafened by the din of their screams of objection at being disturbed. The Hawaiian name for this bird, Ewaewa, means "to make one uncomfortable," referring apparently to their devastating screeching. Their grace in the air is a pleasing sight, gliding with long, pointed, swept-back wings and forked tail. A lovely sight and quite a common one is that of two sooty terns

flying wing-tip to wing-tip across the island at break-neck speed looking for all the world like two expert skaters dashing around the rink hand in hand.

Like all of the sea birds of Midway, the sooty terns spend part of the year at sea and the rest in the vicinity of the island. The return of the sooty tern is announced by an advance flock which arrives some evening in March or April. For days or even weeks they wheel about the island, being joined from time to time by other flocks arriving from every point of the compass. When the size of the flock becomes great enough, apparently, to give them confidence against the many birds already on the island, they land and take over certain areas. After a month or so the large blotchy eggs begin to appear. Both mother and father bird take their turns on the egg, each shift being about a week in length. The free bird spends the time fishing, sometimes quite far from the island. The newly hatched baby is covered by the parent only for the first week or so, and from then on is guarded from a nearby position. The young bird is fed by regurgitation of the small fish and squid caught at sea by the parents. At the end of the summer, around August, the young and old birds leave the island until the following March, staying at sea all this time, it is believed.

The courage of these small birds in defending their eggs or young is a thrilling spectacle. Showing no fear of a human, they will stand their ground and peck at one, while others will fly overhead dive-bombing the intruder with vim but with little effect. It is the spirit of the attack that impresses one, even though the results are meager.

THE FAIRY TERN

Writers have a difficult time expressing the true nature of things at times. When it comes to describing the fairy tern, this normally difficult problem becomes a well-nigh impossible one. In scanning the writing of a number of authors on the fairy tern, such words as "ethereal," "charming," "endearing," "exquisite," "pure," "innocent," are freely bandied about in the attempt to convey the impressions this bird has made on the author. It may seem that these are rather unusual words of description to apply to a bird, but these are just vain attempts to describe this ethereal, charming, endearing bird. This is certain, no mere words will do the bird justice. Only the one who has had fairy terns flutter about his head uttering their plaintive cry or who has had a one-day-old baby stretch out its wings in defiance of a big approaching finger will fully understand this deficiency of words.

The fairy tern *(Gygis alba)* has many other popular names such as the love tern, the Japanese love bird, the white tern. It occurs throughout the central Pacific area. Its plumage is snow-white; it has brilliantly black "shoe-button" eyes which are also ringed in black, and a black bill which becomes bluish at the base. At Midway Islands, they live principally around the ironwood groves, nesting on the limbs of the trees. Before the introduction of the ironwood trees, their favorite nesting spots were in the Scaevola bushes, but they are very adaptable, changing over to rocks on some of the islands where the vegetation was denuded by overpopulation of rabbits.

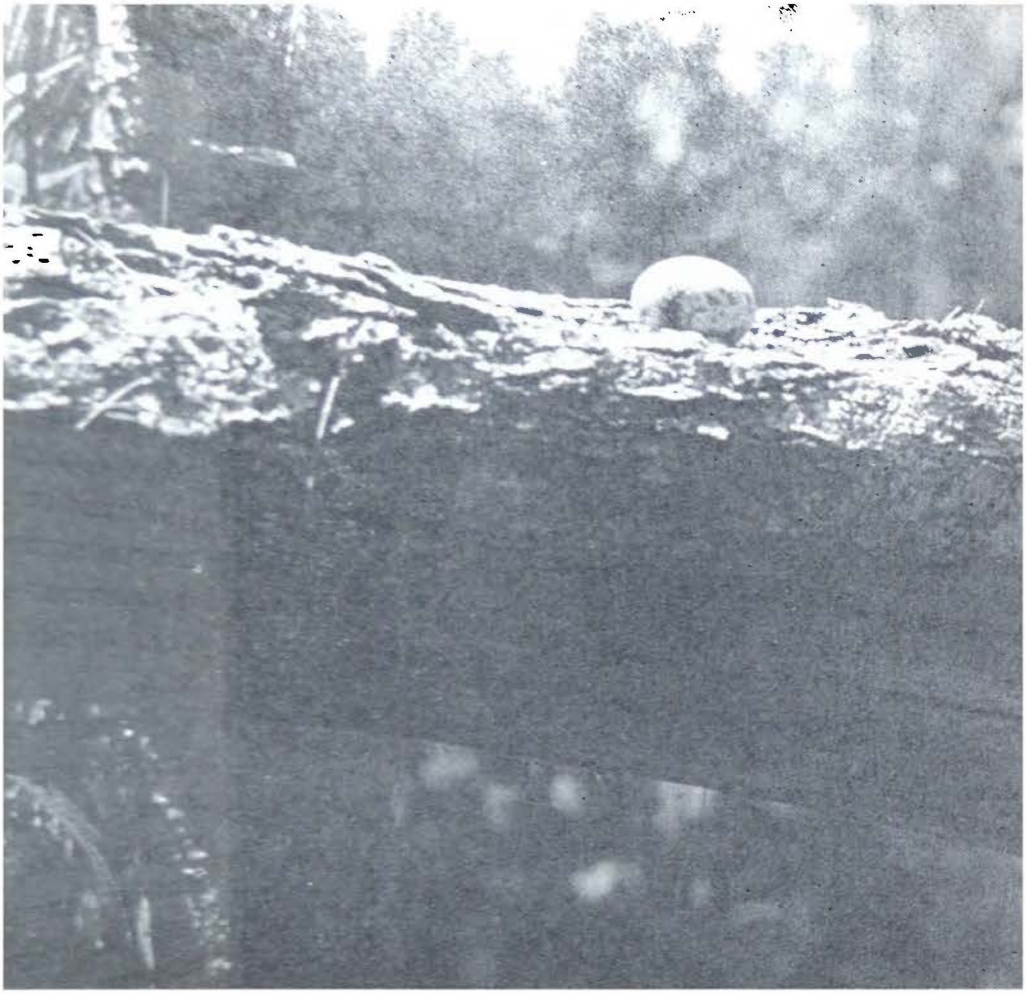
Actually, to find terns nesting in trees is very odd because practically all of the many terns nest in scooped out hollows on the ground. The fairy tern is not satisfied with just changing nesting sites to the lower limbs of trees, however,

The beauty and grace of the fairy tern is heralded around the world. This bird is noted for its habit of laying its egg on a bare branch or in the crotch of a limb where the baby hatches and desperately clings.

but she lays her egg on the bare limb after carefully searching out some insignificant indentation the human eye would have difficulty in finding. Sometimes the egg is deposited in the crotch of a tree or bush, sometimes on the top of a fence post. Eggs are frequently seen caught between two parallel limbs, barely kept from falling through by the slightly greater diameter of the egg. Apparently the tern has a wonderfully accurate advance knowledge of the size of the egg-to-be. On Eastern Island we found one fairy tern egg laid on the window sill of an abandoned hut, and on Sand Island an egg was placed on the 2 x 4 sill of the foundation of a building under construction.

There are many mysteries surrounding the fairy tern: for example, the mode of sitting on the carefully balanced egg without tipping it off. Motion pictures and careful observations show that instead of following the usual habit of fowls of shoving the eggs beneath the breast with the bill — a procedure that would be sure to dislodge the egg — the fairy tern gently touches the egg with the bill as a guide, and slowly and carefully pulls itself over the egg so that the soft breast feathers cover it. Even if one does understand how this difficult feat is performed, it is even harder to understand how the parent tern does essentially the same thing with a nearly fully fledged baby almost as large as the parent!

The hatching of the precarious egg is generally thought by scientists to take place under the feathers of the parent bird. However, there is a legend that says the baby hatches feet first, getting a firm clutch on the limb, and then after this comes on out of the shell! This concept might be a bit hard to establish, but it has the obvious advantage of not seeming exaggerated when one knows the many wonderful and mysterious things surrounding the fairy tern. There is certainly no question about the newly hatched birds having firm grips on the perch. It is practically impossible to lift a baby tern from the limb without running the risk of pulling it apart. These babies are very precocious. One day I noted carefully and even photographed an egg in the crotch of an ironwood tree. To my surprise the next day, there was in its place a tiny bundle of gray pinfeathers which stretched up to its full height of two inches at my approach, stuck its stubby, downy wings out and tried to peck my hand. Watching a baby fairy tern asleep on a wind-blown limb fills one with concern the way it droops over the limb, the head over one side and the tail



The eggs of the fairy tern or white tern is laid in some such precarious position as this on a bare limb.

over the other. The baby's grip on the limb apparently tightens as he tends to roll off.

The feeding of the young fairy terns is another of the mysteries of Midway. For the first week, the baby is fed by regurgitating partially digested food, but after that the adult bird goes out to sea and catches six, eight, or even a dozen, tiny silvery blue fish and brings them back neatly stacked cross-wise in a bill only one and one-half inches long! To this day there is no completely satisfying description of how this is accomplished. The birds have been observed to catch the tiny fish as they jump into the air as larger fish scare them. While they are in the air, they

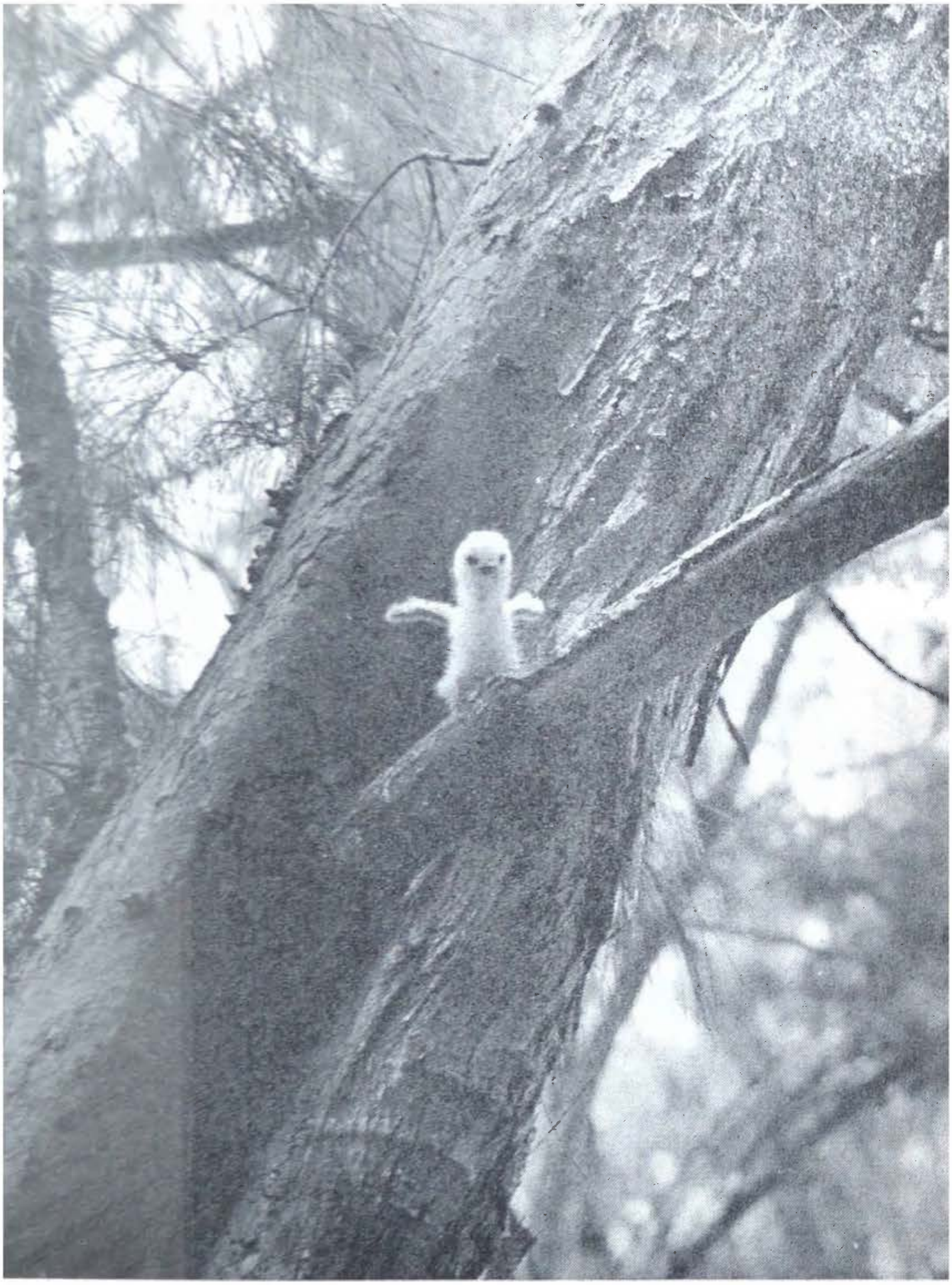
are fair game for the very fast and maneuverable fairy tern which dashes down upon them and catches one in its bill. This fish is then crushed and shifted to the rear of the bill. So far it is easy. Now comes the real test of catching the second one without losing the first one, but catch it he does, never losing fish while new ones are being caught. It seems quite certain that the tongue is used, both in the shifting of the fish and in holding those already caught while swooping for another one. This procedure is put in reverse while the adult bird sits on the limb feeding these fish to the baby. One at a time, in reverse order, the fish are taken from the beak of the adult by the baby.

As terns go, the fairy tern is very quiet. The screaming of the sooty terns on the opposite side of Sand Island is a terrific contrast to the low questioning, plaintive call of the fairy tern. This melodious note is very much in keeping with the beauty and ingratiating ways of the fairy tern as it hovers about one's head, or even landing on the upstretched hand. The Navy and Marine men may have hated the isolation and confinement of a tiny atoll in the Pacific, like Midway, but this can be said without contradiction — they all love these love birds that just assume that everyone is their friend.

THE BOSUN-BIRD

The bosun-bird cannot walk but it can fly backward! It seems that every bird at Midway has some sensational special characteristic. One never becomes great friends with the bosun-bird—he just isn't the friendly kind—but it is a rare person that isn't captivated by its many unusual antics.

The bosun-bird is about 16 or 18 inches long, not including the two beautiful, slender tail feathers of brilliant red about 14 inches long which give it the name of "red-tailed



A baby fairy tern, less than two days old, threatens the photographer with some sort of grave bodily injury. There is a legend that the fairy tern hatches feet first, gets a good grip, and then comes out of the shell!

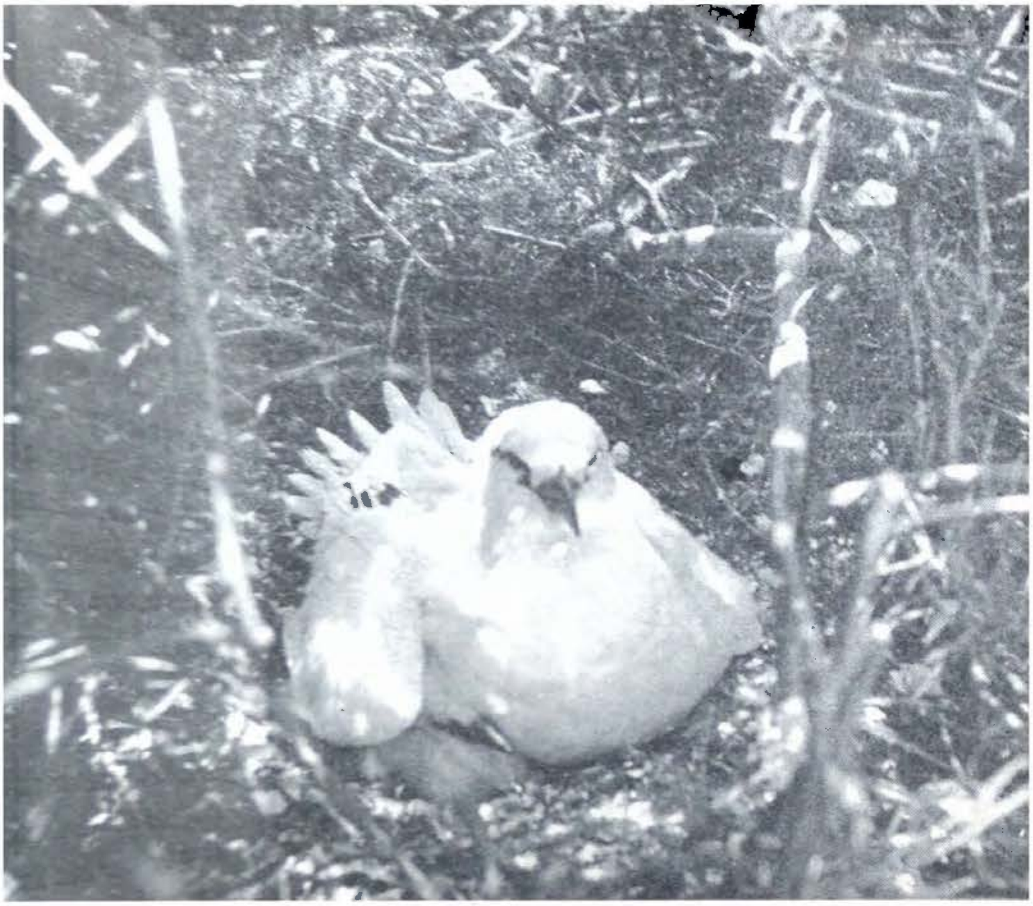
tropic bird." The plumage is a lovely rose-tinged white, with an orange-red beak which opens to a frightening degree and emits a blood-curdling "aaawk" from way down deep when it is disturbed on its nest under the Scaevola bushes.

The bosun-bird cannot stand on its legs and is always seen in a crouching position while on the ground. In taking off there is a sudden flurry of wings and up he goes likes a helicopter. Scientists learned that after banding one of these birds one should not toss it into the air in the time-honored way of launching birds, for when this is done it will come down as relaxed as a bean bag, with serious results.

The bosun-bird (so named by the sailors because it "has a marlin-spike in its tail") arrives at Midway about May and raises its family and leaves about the end of December. But do not think that this time is all work and no play. Quite the contrary, for from about 11 A.M. to 3 P.M. every sunny day, these birds fly over the island and give the inhabitants a treat in the form of an aerial circus. In great squawking groups they indulge in aerial acrobatics which really catch the eyes of the many aviators passing through. A typical performance (all to the raucous accompaniment of all-out vocal efforts) starts with a gliding dive. The bird then hauls back on the stick and stalls, flying up and backwards with its two long scarlet tail-feathers streaming out in front. It appears that the wind assists in the backward component of the flight, but authorities have stated that the performance goes on unabated in a dead calm.

THE MOANING BIRDS

The first night one spends on Midway Island is not likely to be forgotten. After dark when things have really



Another member of the large bird population of Midway Island is the Bosun Bird or Red-Tailed tropic bird which cannot walk but which excells in aerial acrobatics. Note the fuzzy baby under the parent's wing.

quieted down, terrible moans float through the air which would serve well as sound effects for a Hallowe'en ghost story. Cat-like yowls and shrieks and sounds of a woman dying in terrible pain raise the hair on the baldest head. But if one were especially brave and decided to investigate, he would have difficulty locating the source of the sound. Certainly the sailors shipwrecked on this island must have had a few terror-stricken nights during which they wished they were safely at sea clinging to a floating spar. A nocturnal investigation among the bushes is punctuated at very frequent intervals by cries of dismay as one leg after another sinks in the sand up to the thigh. Eventually it

is discovered that the holes and the howls have much in common, for the holes are the homes of the moaning birds.

There are two kinds of moaning birds, the small and the large. The small one is actually the Bonin Island petrel *(Pterodroma hypoleuca)*, noted both for their great numbers — an estimated 500,000 on Midway Islands alone — and the fact that they are exceptional diggers. When a half million birds like the Bonin petrels really set themselves to the task of digging holes in the sand, falling into the holes changes from a possibility to an almost dead certainty if one ventures off the beaten paths of the island. Hadden describes the digging: "They usually get their head or shoulders up against a plant stem in order to get the leverage for digging, and then they make the sand fly. The burrow is usually about six or ten inches below the ground, and three to four feet long. They toss the sand out of this hole to a distance from eight to ten feet, using first one foot and then the other. A rabbit couldn't dig a hole any faster than they do."

The big moaning bird can be identified as the wedge-tailed shearwater *(Puffinus pacificus)* called the Uau Kani, or noisy uau, by Hawaiians. Strange as it may seem, the ghoulish noises put out by this bird are its love song, appreciated, apparently, only by another big moaning bird. This continues for several weeks as these birds throw their heart and soul into their crying, their throat swelling with emotion. After this period of moaning, the digging really begins. The big moaning bird is also a wonderful digger, digging a hole that is larger and deeper than that of the smaller bird. The length is usually about four or five feet, and the diameter is about ten inches. Of course this larger hole makes an even better pitfall for the unwary, or even the wary walker, and the full range of Naval vocabulary

s usually called upon to express the feeling toward such birds when a sailor falls through.

Hadden tells of an amusing incident, amusing to everyone but the gardener at Midway. This man had just laboriously made a nice garden while the moaning birds were away. One evening he went out to see how the things were coming along and carrots, beets, radishes, and lettuce were flying in every direction. The big moaning birds had returned to Midway! He counted 1500 of them busy on a three-quarters of an acre plot! Funny? Well, this depends entirely upon your point of view!

THE BOOBIES

A trip to Eastern Island is an event long to be remembered for the lover of nature, for here the boobies and the frigate birds live. Of course there are many other kinds as well — the albatrosses, and fairy terns; but in certain areas the frigates and the boobies have taken over with their nests of sticks atop and beneath the Scaevola bushes.

There are three species of boobies or gannets on Midway Islands: the red-footed booby, the brown booby, and the blue-faced booby. These birds are large, long-winged sea birds with beaks which are sturdy and conical. Their legs are very short and stubby, and their tails are long and wedge-shaped. The terms gannet and booby are applied more or less interchangeably, the latter and less elegant name being given to these birds by early sailors because of the apparent stupidity of the birds. When they land aboard ship, or ashore, they can usually be approached and picked up without trying to fly away, although they will probably try stabbing the intruder with their sharp beaks.

The gannets are noted for their diving prowess. They commonly dive from heights of 50 and 60 feet, and at times

A Booby or Gannet on Eastern Island, Midway Islands.

from heights of 100 feet. When a bird is seen to dive this way, one can be quite sure that it is either a gannet or a brown pelican, and a glance at the bill should leave no doubt in distinguishing one from the other. Terns, much smaller, and tropic birds with long tail feathers, also dive. The booby attains considerable velocity in diving from such an altitude, and it is not surprising that it dives to great depths as well. Not satisfied with just diving upon a fish, it pursues it under water, swimming at top speed. Fishermen have caught these birds in their nets at a depth of 90 feet.

THE FRIGATE BIRD

"A sea fowl that cannot swim; a fish-eater that never touches water save with the tip of its bill; a glider equipped

with elongated planes but devoid of landing gear with which to take off or return on any level surface; a being with the pinions of a dark angel, the insignificant feet of a humming bird, the code of a buccaneer — such is the frigate bird or man-o'-war." So Robert Cushman Murphy, one of the truly great students of the sea birds, sums up the pirate of the air which pursues his thievery from Cancer to Capricorn, around the world.

The frigate bird, or man-o'-war, or sea-hawk, or eagle of the sea, is the greatest master of flight among all birds, fully capable of earning its living by honest means. They can snatch fish from below the surface of the sea so stealthily that the school of fish is not even disturbed. A more exciting method of earning an honest meal, however, is to fly at considerable altitude, spot a baby tern or a flying fish on the wing, and then power-dive at breakneck speed to the catch. The victim thus caught is tossed into the air and recaught apparently to line things up for an easier swallow!

But doing things the legal and socially accepted way is not one of the strong points of the man-o'-war. Why not coerce the other birds to do the heavy work, and then intimidate the food from their grasp? Here the poor boobies feature prominently, for they are most often victimized. Soaring gracefully, a careful watch is kept for the homeward bound booby coming in from the sea with a cropfull of delectable fish. The rogue of a freebooter chases the artfully dodging booby until it is apparent that there is just no losing the black monster. It is interesting to conjecture whether the booby knows by instinct what to do, or whether it was learned in the school of hard slashes from a deadly hooked bill. But anyway, it knows what to do and forthwith disgorges some of the food caught at sea.

The Frigate Bird, or Man-o-War bird is a master of the art of soaring and playing the pirate. The male bird, sitting, has a large scarlet pouch under its bill which may be filled with air until it looks like a red balloon.

The frigate forgets the chase and dives to recover the loot which rarely has time to hit the water. There is a legend that the booby stows his favorite squid below some less delectable fish, so that when forced to disgorge, the tidbit can be salvaged from the affair! The boobies share this doubtful distinction of being the object of affections of the frigate with the bosen bird, terns, pelicans, gulls and cormorants.

The strange thing is that the boobies that are its dupes in the air, are its closest neighbors while on the ground. For instance, at Midway the red-footed booby and the frigate nest in the tops of the bushes only a few feet apart. While on the nest, the pirate of the air has a disposition of the model neighbor, paying no attention to his meal ticket a wing length away. Perhaps more surprising is that no hard feelings seem to be borne by the booby. But

there is a constant feud (again with no hard feelings either way) concerning the legal tender of the Midway set—sticks for nests. If both boobies of the pair leave the nest, all sticks will be gone when they return — stolen by the neighborly frigates, or even other boobies. The same thing happens to the nest sticks of the frigate if its nest should be left unguarded for a moment. It could be funny if only sticks were involved, but the sad thing is that the babies can be stolen this way too, and not to line a neighbor's nest.

The frigate bird is principally black in plumage with white areas beneath. This varies among the five species, but the lesser frigate bird found at Midway is almost entirely black in the male while the female has a white breast. The bill is long and slender and equipped with a sharp hook at the end. A patch of naked skin on the neck beneath the bill is only that in the female, but in the male this skin is extensible and of a vivid red color and during the mating season he blows it up like a toy balloon to impress the lady of his choice and to amaze the incredulous human onlooker. A diameter of eight inches is frequently attained, looking for all the world like frigate birds have taken up bubble gum! When driven from the nest with the balloon inflated, he flies around with this great scarlet sac dangling, a most grotesque ruby-throat.

The feet of the frigate are weak and dainty, and scarcely strong enough to cling to a perch during the night. On Eastern Island we found one frigate which had landed on the ground by accident or force of circumstances and he was unable to take off. His legs would not bear him up so that his seven foot wings could operate. Landing on water is usually done on pain of death as well. But from the five-foot elevation of the tops of the Scaevola bushes, the frigate has no trouble in launching itself.

In flight the frigates are a beautiful sight. No effort is expended in keeping aloft like so many other sea birds. A group in flight heads into the wind, sailing from side to side without progressing, long forked tails opening and closing, and heads moving from side to side. They hover hour upon hour, day after day, but they usually choose to return to their nest or favorite roost to spend the night. A strange sidelight is that while on these roosts at night they become stupified with sleep so that humans can easily catch them. In early days they were killed for their fat which was supposed to cure rheumatic pains, and Samoans catch them and train them for message-carrying duty much as carrier pigeons. The satisfaction with which they take up a peaceful abode on a perch with a tether on their leg seems strangely foreign to this regal pirate of the air and tyrant over other birds. However, as Robert Cushman Murphy suggests, it may be in exultation over having captivated an exceptionally large and docile being into supplying the necessary fish without the necessity of turning a feather!

If the frigate is the best aerial performer among all birds, it is because he is built better for this function. Murphy cites a Caribbean frigate of 89-inch wing spread which weighed only 2 lbs. 2½ ounces. When dried, the entire skeleton of this bird weighed only ¼ pound. To emphasize how definitely these birds are built for flying, the breast muscles which propel the wings comprise a quarter of the entire weight of the bird, and the *feathers* another quarter! Compared with other sea birds of the same weight, the frigate has 40% more wing area. Strong muscles are of value only if strong attachments to a sturdy frame are also provided and we find special provision for this, the wishbone being fastened to the keel of the breastbone and to the two lateral stanchions of the shoulder girdle.

THE GOONEY BIRD

Are all the birds of Midway world-famous for something or other? The bird that lays its eggs on a bare limb, the bird that flies backwards, the bird that indulges in aerial acrobatic tricks each day, and the pirate of the air that steals its food from its next door neighbor. Surely this fills the quota of wonders for two tiny sandy spots in a six-mile lagoon! Not so, there is still the gooney bird! This bird, in addition to his dancing ability, is a master of flight. The gooney bird (from the English dialect word *Gony*, meaning simpleton) on Midway is the term given to two of the albatrosses, the black-footed albatross *(Diomedea nigripes)* and the Laysan albatross *(Diomedea immutabilis)*. Unlike the great wandering albatross of ten or twelve-foot wingspread made famous by Coleridge in *The Ancient Mariner,* these do not follow ships at sea although the months from August to November are spent away from their breeding grounds on Midway and other islands of the North Central Pacific, apparently ranging the open ocean. These birds are as large as a large goose and have a wingspread averaging about seven feet. The Laysan albatross, or white gooney, has a snow-white breast and underparts and blackish brown on the back and wings. There is a beautiful delicate shading of pearl grey about the eyes. The black gooney is dark brown above and somewhat lighter below, and has a white patch on the tail and a white ring around the base of the bill. The bill is a strong weapon, hooked downward on the end, and eagerly used to scare humans venturing too close. The gooney walks on wide-set feet and legs, and the side-to-side wobble gives one the impression that the bird has very sore feet.

In the air these birds are a beautiful sight as they gracefully soar or swoop at dangerously low levels over the sea,

dipping to the very surface of the waves and even dragging a wingtip across the water surface at times. Getting into the air is a difficult proposition for a bird as heavy as these, especially if the wind is not very strong. Under such conditions a long run with outspread wings until a speed of about 25 miles per hour has been attained is necessary before it becomes airborne. It is a real question how the goonies managed it before the airfields were built, as roads and airstrips are regularly used for take-off purposes.

While visiting Midway during the war, I went up on the "hill" to visit a friend at the radar station. As we were talking beside the building, we noticed a white gooney running toward us as fast as his feet could carry him, wings and neck outstretched. He had it figured to become airborne opposite the building, not realizing the effect of the building upon the local air currents. He managed just barely to get his feet off the ground when he hit the turbulent air and lost flying speed. At this point he put out his feet and tumbled end over end in a flurry of coral sand! This was funny enough, but the way the bird shook himself, looked back over his shoulder with a haughty stare at our insolent laughter, and wobbled off in dignity had us all holding our sides in merriment.

On this same visit two of us were walking along a path when a resounding crash in a nearby ironwood tree startled us. We looked up and here was a gooney bird tumbling from limb to limb and finally hitting the ground with a thump. Apparently this was a small thing in the gooney's day, for he shook himself and walked away in an unconcerned manner.

The Laysan and blackfooted albatrosses leave the island in August and return about November. After spending these months at sea, where a landing on the water is successfully culminated by sliding in with feet up-turned like

skis, it is said that their first landings on the sand are really something to behold.

The nest is constructed by making a shallow identation in the sand but it is well marked in a short time by the radial spokes of excrement and the debris of the fishy meals brought in by the parent. These nests are placed almost anywhere, frequently in the center of a lawn, in the middle of a road or path, and elsewhere where the human inhabitants fail to see the logic of the choice. Water from a lawn sprinkler raining down upon a wet and bedraggled baby gooney that is unable to move, and monstrous Navy trucks and trailers swinging off the road to avoid a baby in its nest is all in the day's work for the gooney and the Navy personnel.

The gooney pair treat their one egg with great consideration, taking turns sitting on it while the mate goes to sea fishing. There is considerable bowing to each other accompanied by much discussion during the changing ceremony. The parent preparing to settle on the egg "talks" to the egg and nuzzles it fondly with its bill.

The baby bird is fed by regurgitation by the parents. In mid-May, 1951, I watched a parent Laysan albatross feed its large but helpless baby by this method. In the space of six minutes I counted 17 regurgitations eagerly followed by the baby. Just how much actual food was transferred is unknown, but it seems apparent that such a big hulk of a baby would require a considerable amount of food. As the parent returns from the sea, the baby begins nibbling the parent's bill and emitting a plaintive cry which sounds very much like children begging a slice of bread and jam after school. The parent stands its ground, moving the head from side to side trying (but not very hard) to avoid the nibbling. Such antics start the serving up of the food and precede each following serving.

Chapter 10

THE SEA ELEPHANT AND THE ULCER

As the Velero IV cautiously approached Guadalupe Island in search of a good anchoring spot, a dark object suddenly rose from the water just off the bow. It stood upright in the water like a weighted totem pole and the gargoyled top was something no Indian sculptor could possibly have imagined. It was a giant sea elephant or elephant seal floating upright in the water. He surveyed the great white apparition before him with apparent approval and with his long, flexed proboscis dangling into his open mouth he let forth a mighty series of "chung—chung—chung" noises sounding like a resonant pile driver. The echoes tossed back by the volcanic cliffs produced an eerie syncopated rhythm as the gargoyle slipped beneath the water.

Going ashore in the skiff, we rowed between many other great hulks floating leisurely in the water like hippopotami occasionally exhaling in a cloud of spray with an awesome snort.

Once on the beach we cautiously picked our way around the sleeping forms of hundreds of the massive beasts but we soon discovered that rather than being threatened by these giant sea elephants, we were being royally and regally snubbed—they kept on sleeping. With characteristic human

The many aviators stationed at Midway during the war were particularly aware of the gooney's prowess in the air. They were inclined to forgive a few rough take-offs and an occasional pancake landing when they saw one soaring. But with the young gooney they had a barrel of fun, especially along about the time the babies were beginning to stretch their wings and feel the pull of the winds. The fighter planes were scattered all over the islands as a precautionary measure in case of a surprise raid. Most of them were in revetments, surrounded by a hummock of sand on three sides. When the goonies arrived, eggs were laid all around the planes and over the revetments. In the daily "ready" drill, the engines of the planes were warmed up. During this period, the birds in the wash of the propeller would stretch their wings. This was the signal for the full gun which lifted the birds right up into the air where they hung until the throttle was suddenly cut. It is said that even the thumping of the return to earth was not enough to discourage the bird, and thus was forged another tie binding the fighting man to one of the most peaceful of all birds, the gooney.

The sea birds of Midway Islands go about their established pattern of life without paying too much attention to the noisy, mechanical birds which come and go. To the thoughtful observer, however, a giant transport roaring down the runway is deeply in debt to the bird scurrying out of the way. The one so great and powerful, the other so delicate and beautiful, and yet to these birds we owe the very idea of flight as well as the principles which make it possible. But birds are merely creatures from the hand of God, and we are again faced with the inescapable conclusion that God is the Originator of the very foundations of the science and industry of aviation.

A bull sea elephant of Guadalupe Island records his impressions of life by portable magnetic recorder operated by the author.

nature, we proceeded to do something to proclaim our presence and to insist on being noticed. A brisk prodding with the business end of an oar finally caused a giant bull to open his portside eye just a crack, but the starboard eye didn't budge. Nor was what he saw enough to keep the portside eye open, so it lazily closed to the accompaniment of one of the most impressively bass and masculine snores I have ever heard. The first impression was that this was the last breath of this magnificent physical specimen, but after a time interval befitting such bulk, another lungful was expelled with the snoring sound caused by the rush of air through the dangling proboscis.

The sea elephant, or elephant seal, is the largest of all

seals. A length of sixteen feet and a girth of eleven or twelve feet are not unusual for an old bull. The largest ever recorded was "twenty-two feet long from tip to tip and yielded 210 gallons of oil," as written by Charles M. Scammon in 1870. Scammon referred to the existence of others of twenty-four foot length. A large male sixteen feet long is quite common, and such an animal would have a flexible proboscis eighteen inches long and would weigh approximately 5000 pounds. The females rarely exceed a length of ten feet.

There are very few spots in the world where these unusual creatures live. South Georgia Island, lying a thousand miles east of Cape Horn, is the principal home of the Southern Elephant Seal. At one time the Northern Elephant Seal ranged from San Francisco 800 miles southward to Cape Lazaro, Lower California, but the whalers changed all that. Their slaughter of these animals was so great that at one time it was believed that none remained. Fortunately, a few escaped, and a herd began to build on Guadalupe Island, a Mexican Island 225 miles south of San Diego and about 200 miles off shore. The Mexican government passed laws protecting the elephant seals, and today the herd numbers around 5000, and some of the Channel Islands off Southern California have small herds.

The Society of Elephant Seals is a highly organized one ruled by a hierarchy of old bulls. These bulls lord it over the harems and maintain their place on the ladder strictly by fights between competing males. It is a strange sensation to be in the midst of a group of sea elephants all of which are apparently sound asleep when suddenly two monstrous bulls rear up as if by a pre-arranged signal and direct savage downward slashes of their tusks at the calloused breast and tender proboscis of the opponent.

A sea elephant family group displaying characteristic activities: Father sleeping with great proboscis trembling as he snores, baby searching for something to eat, and mother ready to attack anything appearing to threaten her baby.

Most of the males have blood-smeared "shields," but the tough, horny covering is like shoe leather and it takes a well-placed slash to do much damage. The babies are coal black with large lustrous eyes rimmed with what appears to be tears, and these eyes are enough to melt the heart of the toughest man. But beware if you feel the urge to pet one of these little ones—the mother seal keeps constant vigil and any threat to the safety of her baby precipitates a rapid advance accompanied by a series of wheezy coughs which throw saliva a dozen feet.

It is not only the baby seals that have large and luminous eyes—this holds for adults as well. A frequent occurrence is a drainage in the corner of the eye that gives

Female elephant seal of Guadalupe Islands defends her baby by an attack, raucous sounds, and a barrage of flying saliva.

this seal the appearance of injured dignity and sadness. Such large eyes suggest great nocturnal activity and use at great depths.

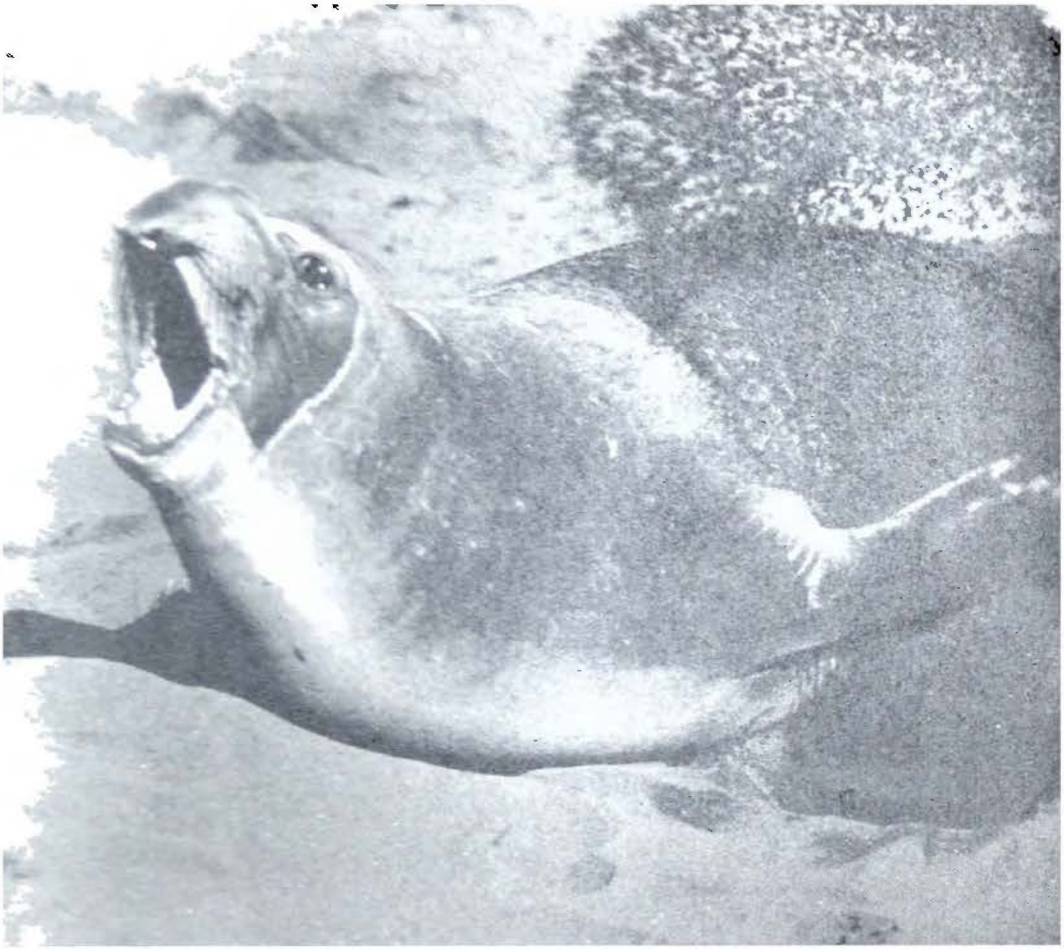
The mode of movement on dry land can be roughly compared to a three-ton measuring worm. The problem of supporting and moving such weight ashore is very great and it is usual for a great bull to propel himself down the beach by a series of rhythmic waves and then suddenly to cast himself full length and immediately fall asleep. When underway, the fore flippers are employed to hold up the front part of the body in the forward surge of the undulatory movement. The tail flippers do not contribute to movement on land, but merely drag along behind. In the

The peeling pendulous proboscis of a giant sea elephant on the island of Guadalupe, one of the Mexican Pacific Islands. (These animals attain lengths of 16 feet and weigh up to 5,000 pounds.)

water, the reverse is true. The foreflippers are inactive in rapid swimming and are only called into service when the speed is very slow at which time they act as balancers. When the seal is full speed ahead under water, the motive power is supplied by the powerful hind flippers alone acting in vigorous lateral sculling motion. Under such conditions they can travel from 10 to 14 miles per hour in a very graceful fashion.

Resting in the water seems to be no problem to the sea elephant. He can float vertically or horizontally in the water with no apparent effort, and he can also lie motionless on the bottom. It is amusing to see him go up and down as he breathes while floating in the vertical position.

A most understandable human impulse is to want to



Aside from sleeping, the next most characteristic action of elephant seals is tossing the black volcanic sand on their backs, apparently to discourage flies. (Photo courtesy Allan Hancock Foundation, University of Southern California.)

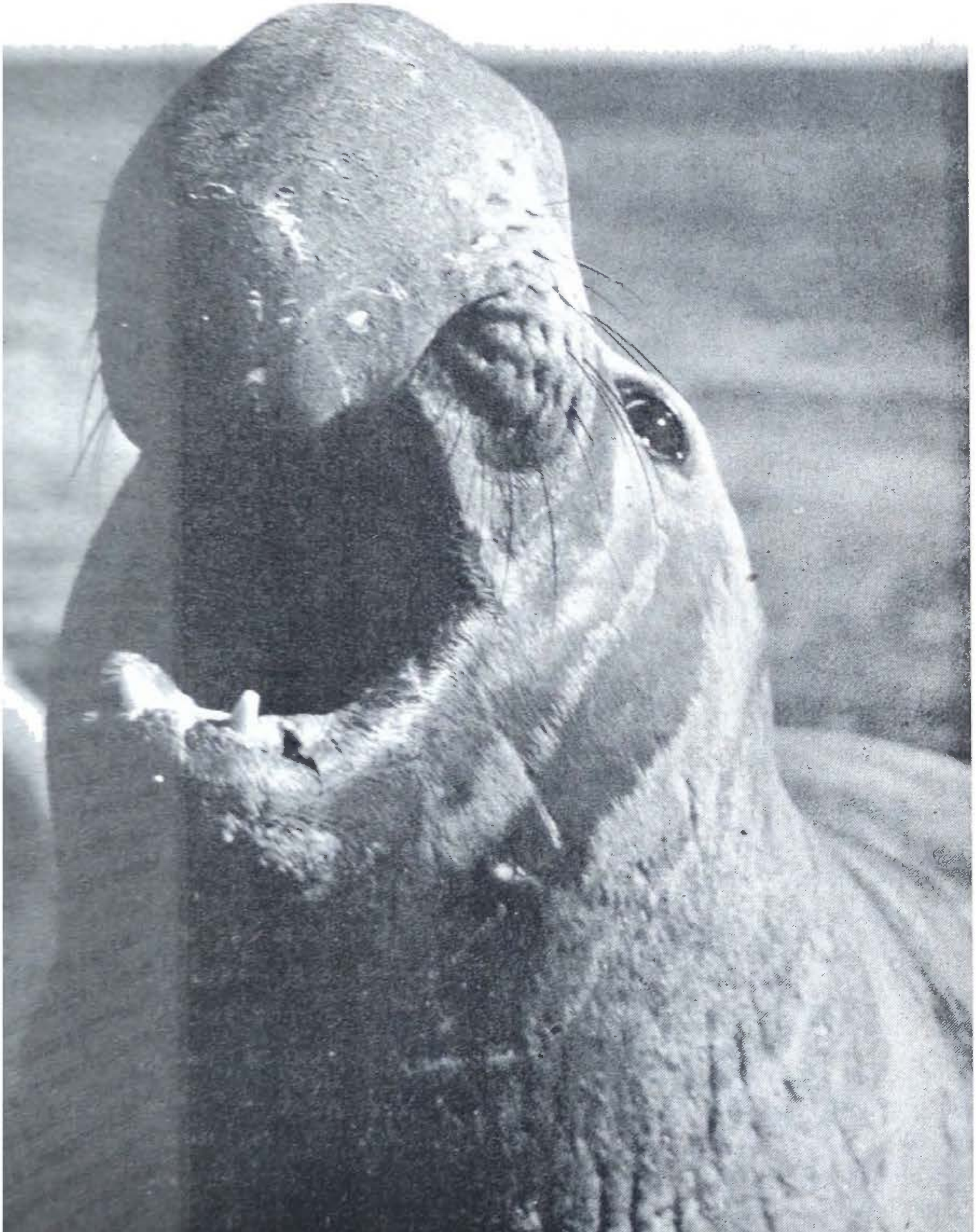
capture some of these magnificent animals for display in zoos. Their rarity, their great size, and their amusing appearance make them the zoo-keeper's bane and delight. Captain Allan Hancock has made expeditions for the purpose of capturing these animals alive.

Breaking an elephant seal to the routine of zoo life is anything but an easy task. At the famous San Diego zoo, one elephant seal held out for 157 days before co-operating in the matter of taking food. During this time it was forcibly fed with the assistance of a canvas strait-jacket and an iron bit in its mouth. The animal finally decided to eat under its own power but the canvas jacket was still needed for psychological encouragement.

Strange to say, most of the captive elephant seals succumb within a few years, even though the feeding problem has been solved so successfully that supplying enough sardines is a major problem. When such animals died, zoo officials tried to determine the cause of death. When dissected, open ulcers were found in the stomach and intestines. The cause of such was laid to the artificial conditions of zoo life.

By special permission of the Mexican government a few animals were later taken at Guadalupe and examined. To the great surprise of the scientists examining the digestive system of the animals, ulcers were again found! However, there was one difference: in the stomachs of the seals killed on the beach of Guadalupe, each ulcer crater harbored a colony of round worms! Careful study revealed the amazing fact that under natural conditions colonies of these worms thrive in the stomachs of the elephant seals, and that they keep the ulcers under control. In captivity the worms died allowing the ulcers to grow and eventually perforate the walls of the digestive tract. Probably the chances are quite remote that the elephant seal's cure for gastric ulcers by nematode worms will become popular among humans.

Accelerated living is taking its toll in the health of modern man. He is working his brain overtime to invent new and different things, and what does it get him? Ulcers! In our search through the realm of nature our strangest discovery is that even in this ridiculous case of the ulcer, the very badge of modern inventive man, nature had it first! We can no longer point to this symbol of the driving industrialist with any sense of pride of attainment, but only with the realization that the gastric ulcer is something sea elephants have had all along!



Bull elephant seal emitting his challenge call. The relaxed proboscis hangs in the open mouth, giving a resonant character to the "chung-chung-chung" sound. (Photo courtesy Allan Hancock Foundation, University of Southern California.)

Chapter 11

THE CLAIM OF CLAIMS

MAN HAS TAMED the thunderbolt and compelled it to turn the wheels of industry and do menial chores for the housewife. He has used his brain in taming the forces of nature and bending them to his use. While he has used but a tiny fraction of his brain's capacity in all of this mental activity, the question logically arises, where did he get his brain? If it is the capstone of eons of random development, how can one account for all of the unused capacity? The only satisfactory answer — the only answer that seems to fit the records of nature and of the Bible — is that this brain has been given to man by God. Not only have man's great inventions been anticipated by God in His created things, but the very mental equipment man utilizes in his inventing is straight from God's hand as well!

This human brain has been subjected to much specialized study, and some startling things have been found. Dr. W. S. McCulloch has compared the functioning of the brain with some of the newly developed electronic computing machines. At the time of the presentation of his paper before the American Institute of Electrical Engineers, the most complex calculating apparatus devised by man was the ENIAC, an instrument having some 18,000 electronic relays. A calculating machine which would be somewhat comparable to the human brain would contain 10 billion electronic relays and would take a building the size of Chi-

cago's Merchandise Mart to house it, all the power generating capacity of Niagara Falls to power it, and all of the water of Niagara Falls to cool it! Of course, this is only a superficial comparison for there are many functions of the brain not fully understood. Man's computer, the ENIAC, could thus be rated about as intelligent as a flatworm.

Practically all that man knows he has learned from the experiments and mistakes of others. Man toys with the marvels of creation, pokes in the profound mysteries of life, and in some way emerges with an air of accomplishment and ill-concealed pride as he expectantly glances about for the medals that should be hung on him. Is he really adding anything to what is already here, or is he just uncovering what God has built into this old universe? It is a worthy achievement for scientists to learn of the workings of matter at the atomic level and be able to transmute elements, but in giving the credit let's not forget the almighty God who made those atoms, who established all these laws of atomic physics, and who stacked them in the middle of the sidewalk so that eventually some man would just naturally fall flat on his face in the midst of them. What man needs is a better perspective. If it were possible for us to catch just one fleeting glance of things from God's point of view, I am sure we would see the true fumbling nature of man's most heralded achievements.

God has a rightful claim on your life and mine. He has a claim on us because He made us, a claim of ownership based upon origin. He made us for a purpose, and even though we avoid acknowledging His eternal purpose for our lives, His claim remains.

We are alive only because we are the unthinking recipients of God's providence from moment to moment. Every

breath we breathe, every bite we eat, every beat of our hearts is from His bountiful hand. The favorable environment upon this earth exists only because God, in His providence, has seen fit to arrange things in the proper way. If the earth were just a little closer to the sun, if our atmosphere were slightly higher or of different composition, if the earth were tilted differently on its axis, or if water froze at a much lower temperature, life as we know it could not exist for long. The delicate balance of the pulls and pushes and the advantages and handicaps in nature make it possible for us to survive. Is it not reasonable to think that the God who sustains us by providing all these vitally necessary things has a claim upon our lives?

The providing of all these things upon which our physical lives depend so completely is evidence of God's concern for us. However, from God's vantage point, this physical life is only an insignificant part, and He is more concerned about our relationship to Him in this life and the life to come. In His Word He plainly states that the person that is not for Him is against Him. This is perfectly logical and it has a great bearing on our welfare in the future life. The Bible is our guide book in this realm and it tells us that Almighty God, the Creator and Sustainer of all, the Everlasting One, is the Ruler of both Heaven and earth. It tells us that there is a great warfare going on between the spiritual forces of darkness and God's forces of light but that the forces of light will prevail and they will rule throughout eternity. This battle is being waged in every life, and without the spiritual assistance of God Himself we cannot win. Here enters the majestic love of God for man and His great mercy in sending His Son, Jesus Christ, to pay the death penalty, that is in justice ours to

pay. Our sins waft up as a stench in the nostrils of God. Man's highest moral standards fall infinitely short of the purity and righteousness of God. While man would prefer to compare himself with his neighbors, it just happens that God has established the rules of the game and He has set Christ before us as the standard.

These are things that will never be comprehended in any fullness by the mind of mere man, but in the Bible we can see God's plan, even though we cannot understand it fully. His law states that "the wages of sin is death" and that man's best works can earn him no more than death and eternal separation from God. In His great love for man He sent His Son to die in our place and thus satisfy the infinite justice of God. God has done His part, a part of infinite mercy and love, but it is up to us to do something before this great transaction is finished as far as we, as individuals, are concerned. We must accept this pardon, we must turn our wills toward God and submit to His ruling if we are to enter into all that the great God of the universe has in store for us.

What infinite egotism of man is expressed in the infamous lines of *Invictus:*

> I am the ruler of my fate,
> I am the captain of my soul!

Man does have the freedom to defy the God of the universe in this way, but it carries its penalty of death. What appears to be bondage in submission to God's will turns out to be a most magnificent and complete freedom, a freedom whose long arm reaches into every area of our lives and into the life beyond the grave.

God's prior claim thus extends to a claim on our lives because He has purchased us with Christ's blood on the

cross of Calvary. Man's so-called independence and dominance begins to look rather feeble in our eyes as we contemplate the all-powerful and all-knowing nature of God. Genesis states that man was made in the image of God and it is only in complete alignment with God's will that purpose and true happiness will ever characterize our lives. The humble trapdoor spider, the archer fish, and the rattlesnake have therefore taught us a lesson of eternal significance: that God was there first, that He has the prior claim not only on man's inventions but on man himself.

APPENDIX

Digging into unusual subjects in unusual places yields not only much information on these subjects, but many friends as well. We pass on to other subjects, but we are delighted to find that the friendships remain. Without the co-operation of many such friends, photographic coverage of many of these strange organisms would be impossible. For this reason, the Moody Institute of Science gladly acknowledges its great debt to those listed below and others who have given so freely of their time, energy, and information.

Thanks are due to Mr. Donald Stryker and Mr. Roy Lundholm for showing us the hard-to-find haunts of the cobra plants, and for the hospitality of their home. Mr. Henry Rehder of Wilmington, North Carolina, assisted in locating specimens of the Venus's fly-trap and the North Carolina Department of Conservation and Development promptly gave permission to gather specimens for photographic purposes. Setting up an indoor studio away from the laboratory has its problems; but they are very small ones when such gracious friends as the W. H. Bradley family of Winter Park, N.C., open up their home and make available a workroom to total strangers.

Mr. Lee Passmore of San Diego, California, the dean of trapdoor spider specialists, most graciously showed us his very excellent collection of still photographs representing many years of patient labor. It is no accident that most of

the published photographs of this spider bear credit to Lee Passmore. We are also grateful for the assistance of Mr. Bucky Reeves of San Diego for his photographic coverage of the wasp which preys on the trapdoor spider. Dr. W. Dwight Pierce, Curator of Entomology, Los Angeles County Museum, was very helpful in advising us in searching for trapdoor and bolas spider specimens.

To Mr. Ray Kemery of Santa Monica, California, and to Mrs. R. J. Welch, missionary in French West Africa, we extend our thanks for assistance in supplying chameleon specimens.

Mr. Charles E. Hutchinson, Glendale, California, is the author of the 1903 paper on the bolas spider. This paper is almost unique in giving a detailed description of the actions of this spider. Mr. Hutchinson kindly reviewed our early footage on this spider. Thanks also to Mrs. Martha Penfield Brown for her patient work during our early acquaintance with this most exasperating spider.

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